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THE UNIVERSITY OF ALBERTA

THE EFFICACY OF ASCORBYL PALMITATE IN ENHANCING THE STORAGE AND HEAT STABILITY OF CANOLA OIL

BY

© LYNN MARIE MCMULLEN

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

IN

FOODS

FACULTY OF HOME ECONOMICS

EDMONTON, ALBERTA

SPRING, 1988

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submitted by Lynn Marie McMullen

in partial fulfilment of the requirements for the degree of

Master of Science

in Foods.

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Date: December 17, 1987

ABSTRACT

The effects of various levels of ascorbyl palmitate (AP) and of butylated hydroxyanisole/toluene (BHA/BHT) on the storage and heat stability of canola oils were determined by sensory, instrumental and chemical evaluations.

Storage stability was assessed using both accelerated and practical storage tests. In Schaal oven tests, chemical and trained panel data indicated that 200 ppm AP was effective in retarding autoxidative changes in the oils. The addition of BHA/BHT, at 100 ppm each, to canola oil, did not improve storage stability. In fluorescent light tests (7500 lux), chemical data for oil samples showed that 200 ppm AP was effective in retarding photooxidative changes; however, BHA/BHT was not. Data from trained panelists showed that the addition of 200 ppm AP to canola oils improved the odor characteristics but not the flavor characteristics of samples exposed to fluorescent light. Results from practical storage tests are inconclusive.

The heat stabilty of antioxidant treated canola oils was examined during extended heating (10 hours/day for up to 10 days), deep fat heating (up to 60 min) and shallow pan heating (up to 12 min). Both AP and BHA/BHT were ineffective in extending the heat stability of canola oils during extended heating. During deep fat (0.189 cm^2/g specific surface) and shallow pan (2.89 cm^2/g specific surface) heating, both AP (200 ppm) and BHA/BHT delayed thermal degradation of canola oils as measured by chemical parameters. However, trained panel data indicated that neither AP nor BHA/BHT extended the heat stability of canola oil.

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1. INTRODUCTION

Canola oil accounts for approximately 80% of the salad oil deodorized in Canada (Statistics Canada, 1986). The demand for canola oil is expected to rise on both the domestic and export markets. Consumer demands have caused a shift from the use of animal fats to the use of vegetable fats for frying in the fast food industry (Haumann, 1987). Countries such as Japan, China and the United States have shown increased interest in canola oil. If canola oil is to achieve its full potential in the marketplace, research on the functional properties of canola oil is essential.

The functional properties of canola oil include physical characteristics and the sensory attributes of odor and flavor. The performance of canola oil as a salad and cooking oil in both consumer and institutional use has not posed problems with regards to physical characteristics. However, canola oil quality has been criticized because of the undesirable odors and flavors which develop during storage and heating. Oxidation of linolenic acid (C18:3) has been implicated as the cause of the development of off odors and flavors during storage and heating of canola oil (Vaisey-Genser and Eskin, 1982; Eskin et al., 1986; Tokarska et al., 1986).

Antioxidants are added to fats and oils to retard the oxidation of fatty acids and thus decrease the development of off odors and flavors. Butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) in combination with citric acid (CA) are commonly used as antioxidants in vegetable oils. However, research has shown these antioxidants to be of little benefit when added to stored canola oil (Vaisey-Genser and Ylimaki, 1985; Hawrysh and Shand, 1986; Tokarska et al., 1986). Investigations of the antioxidant activities of tertiary butylhydroquinone (TBHQ) (Hawrysh and Shand, 1986; Tokarska et al., 1986; Hawrysh et al., 1987) and anoxomer (Vaisey-Genser and Ylimaki, 1985) in stored canola oil have shown that both provide antioxidant protection. However, TBHQ and anoxomer are not licensed for use as food antioxidants in Canada.

There is a need to find alternatives to phenolic antioxidants, such as BHA and BHT, since their effectiveness and safety as additives in vegetable oils are in question. Because of current consumer concerns regarding the source of ingredients in food products, an additive which is derived from physiologically acceptable components may be more preferable to consumers than those obtained from "chemical" sources, such as BHA and BHT. Ascorbyl palmitate (AP) is an ester of ascorbic acid and palmitic acid, both of which are physiologically acceptable. AP has been shown to provide antioxidant protection in various stored oils (Cort, 1974) and in heated oils (Gwo et al., 1985). Information on the antioxidant activity of AP in canola oil is lacking.

This investigation was designed to study the antioxidant activity of AP in canola oil under various storage and heating conditions using chemical, instrumental and sensory evaluation methods. Comparisons of the stability of AP treated canola oils with that of untreated canola oil and with canola oil treated with BHA/BHT + CA were also conducted.

2. LITERATURE REVIEW

Canola Oil

Canola oil is derived from the seeds of the rapeseed species Brassica napus or Brassica campestris. In 1980, the term "canola" was adopted by the Canadian rapeseed industry to identify rapeseed varieties which produce oils low in erucic acid (C22:1).

The fatty acid composition of a variety of vegetable oils is given in Table 1. The low palmitic acid (16:0) and the high linolenic acid (18:3) content of canola oil differentiates it from the other oils. As well, canola oil has a higher oleic acid (18:1) content and lower linoleic acid (C18:2) than most other vegetable oils. Canola and soybean oils have similar C18:3 contents; other vegetable oils contain only trace amounts. The physical and sensory characteristics of canola and soybean oils are comparable (Vaisey-Genser and Eskin, 1982).

Fresh canola oil is odorless, bland and light colored. During storage, canola oil develops off odors and flavors (Vaisey-Genser and Eskin, 1982; Hawrysh and Shand, 1986; Tokarska et al., 1986). Many workers have investigated the oxidation of soybean oils; however, few researchers have studied off odor and flavor development in canola oil.

As early as 1936, Durkee suggested linolenic acid (C18:3) was the precursor of compounds responsible for off flavor development in stored soybean oil. His (Durkee, 1936) findings were based on the fact that

Table 1. Fatty acid composition of vegetable oils

	Oil Type							
Fatty Acid	Canola[a]	Soy[bc]	Sun[bd]	Saff[be]	Corn[b]	Cotton[b]	Peanut[b]	Olive[b]
16:0	3.6	11.3	6.5	6.5	10.4	21.6	10.9	9.5
16:1	0.2	0.1	-	-	-	0.6	-	-
18:0	1.6	4.6	3.9	2.3	2.8	2.6	2.3	3.3
18:1	59.2	25.0	19.1	12.0	26.9	18.0	48.1	79.6
18:2	20.1	51.4	69.9	77.6	56.2	55.8	30.8	5.8
18:3	10.6	7.2	0.1	0.5	2.1	0.4	0.8	0.6
20:0	0.6	0.2	0.2	0.4	0.6	0.2	1.2	0.3
20:1	1.7	-	-	0.3	0.4	0.1	1.4	0.3
22:0	0.3	0.2	0.2	0.3	0.3	-	2.9	0.1
22:1	0.8	-	-	0.1	0.1	-	0.1	-

[a] from present study

[b] adapted from Daun, 1984

[c] soybean oil

[d] sunflower oil

[e] safflower oil, high linoleate variety

-not present

soybean oil, containing significant quantities of C18:3, developed off flavors, whereas low C18:3 vegetable oils, such as cottonseed, peanut and corn, remained relatively stable. Other theories for the cause of off flavors in soybean oil have been postulated (Smouse, 1979; Frankel, 1980a, Smouse, 1985). However, it is widely accepted that oxidation of C18:3 catalyzes the development of off odors and flavors in soybean oil. This theory is supported by the research of Stone and Hammond (1983), who reported that the flavor scores of low C18:3 soybean oil were better than those of high C18:3 soybean oils. Similarities in the development of rancid odors and flavors in soybean and canola oils may be attributed to their high levels of C18:3.

In addition to problems of storage stability, canola oil develops a distinct heated odor when heated to frying temperatures (Vaisey-Genser and Eskin, 1982; Vaisey-Genser and Ylimaki, 1985; Eskin et al., 1986). Eskin et al. (1986) compared the heated odors of an experimental low C18:3 (1.6%) canola oil with that of 2 high C18:3 (5.5% and 9.0%) canola oils. The odor score for the low C18:3 canola oil was significantly better than those for the high C18:3 canola oils. This research (Eskin et al., 1986) confirms the role of C18:3 in the development of heated odors in canola oil.

Although fresh canola oil is a high quality oil, its quality deteriorates during storage and heating. The reduction in quality may be related to the relatively high levels of C18:3 present in canola oil. In an effort to enhance canola oil stability, oxidation of unsaturated fatty acids, especially C18:3, needs to be controlled.

Autoxidation, Photooxidation and Thermal Degradation

Autoxidation of unsaturated fatty acids proceeds via a 3 stage process involving: (1) initiation, the formation of free radicals; (2) propagation, free radical chain reaction; and (3) termination, the formation of nonradical products (Dugan, 1976; Frankel, 1980b; Gunstone and Norris, 1983; Frankel, 1985; Nawar, 1985). The mechanism for the autoxidative process is outlined in Figure 1, where RH and $R^{\cdot}$ represent the unsaturated fatty acid and fatty acid free radical, respectively.

During initiation, the production of free radicals may be catalyzed by thermal dissociation, the presence of metal catalysts or exposure to light (Frankel, 1985). The free radicals formed further the autoxidative process by reacting with O_2 to form peroxyradicals, which can then react with another unsaturated fatty acid to form a hydroperoxide and another free radical. The new free radical then contributes to the chain reaction. Termination occurs when 2 free radicals react to form non-radical products.

The autoxidative process involves an induction period when hydroperoxide formation is minimal (Perkins, 1967; Labuza, 1971; Sherwin, 1978; Nawar, 1985; Warner and Frankel, 1985). The induction period is followed by a rapid increase in hydroperoxides and subsequent hydroperoxide breakdown products. Any oil treatment which could extend the induction period would increase oil storage and thermal stability.

INITIATION $\mathrm{RH} \longrightarrow \mathrm{R}^{\bullet} + \mathrm{H}^{\bullet}$

PROPAGATION $\mathrm{R}^{\bullet} + \mathrm{O}_2 \longrightarrow \mathrm{ROO}^{\bullet}$

$\mathrm{ROO}^{\bullet} + \mathrm{RH} \longrightarrow \mathrm{ROOH} + \mathrm{R}^{\bullet}$

TERMINATION $\mathrm{ROO}^{\bullet} + \mathrm{ROO}^{\bullet} \longrightarrow \mathrm{ROOR} + \mathrm{O}_2$

$\mathrm{R}^{\bullet} + \mathrm{R}^{\bullet} \longrightarrow \mathrm{R}_2$

$\mathrm{R}^{\bullet} + \mathrm{ROO}^{\bullet} \longrightarrow \mathrm{ROOR}$

Figure 1. Mechanism of autoxidation.

Hydroperoxides, the primary decompostion products of autoxidation, readily breakdown by various pathways, to form a variety of volatile and non-volatile products. The secondary autoxidation products of oils, which contribute off odors and flavors, include carbonyls, aldehydes, ketones and alcohols (Sherwin, 1968; Labuza, 1971; Vaisey-Genser and Eskin, 1982). Aldehydes are important during initial rancidity development in vegetable oils, as they can be detected organoleptically at very low levels. Hexanal, a major breakdown product, can be detected at 0.150 ppm in oil (Labuza, 1971).

The rate of autoxidation of a fat or oil is related to its fatty acid composition (Labuza, 1971). Since unsaturated fatty acids oxidize at much faster rates than saturated fatty acids, highly unsaturated vegetable oils, such as canola oil, will become rancid much faster than more saturated oils. Methyl linolenate oxidizes 2 to 4 times faster than methyl linoleate, which in turn oxidizes 10 to 40 times faster than methyl oleate (Gunstone and Norris, 1983).

The reactions which occur to form hydroperoxides during the exposure of vegetable oils to light (photooxidation), are similar but not identical to those which take place during autoxidation. Photooxidation proceeds at a faster rate than autoxidation, and requires the presence of singlet oxygen (Gunstone, 1984). Singlet oxygen is generated by exposure to light in the presence of a sensitizer, such as cholorophyll in vegetable oils. During photooxidation, singlet oxygen reacts directly with double bonds to form hydroperoxides (Frankel, 1985). Photooxidation does not involve free radical formation (Carlsson et al., 1976; Frankel, 1985). The products of autoxidation and photooxidation differ in that the autoxidation of methyl oleate yields 4 hydroperoxides, whereas only 2 are formed by photooxidation. The reverse is true for methyl linoleate, while methyl linolenate autoxidation yields 4 hydroperoxides but 6 are formed during photooxidation (Gunstone, 1984).

The application of heat to an oil, as during deep fat frying, combines the effects of autoxidation and thermal degradation. Since heating oils to high temperatures accelerates autoxidation, no induction period is detected (Hess and O'Hare, 1950; Erkilla et al., 1978; Gordon, 1986). During frying, oxidation, hydrolysis and thermal degradation alter the functional, sensory and nutritional quality of the fat (Stevenson et al., 1984b). The changes which occur during deep fat frying are illustrated in Figure 2.

Thermal oxidation of an oil results in the formation of both volatile and non-volatile decomposition products (VDP and NVDP, respectively) by numerous and complex pathways. During oil heating, the production of VDP alters oil odor and flavor characteristics (Roth and Rock, 1972; Blumenthal et al., 1976; Mounts, 1979). During frying, VDP can cause changes in the odor and flavor characteristics of the fried food (Chang et al., 1978). Creation of NVDP, due to thermal oxidation and polymerization of fatty acids, results in a variety of physical and chemical changes in the oil. These include darkening of oil color; increases in viscosity, foaming, free fatty acid content, carbonyl value, hydroxyl content and saponification value; as well as decreases in smoke point and unsaturation (Bracco et al., 1981; Perkins, 1967).

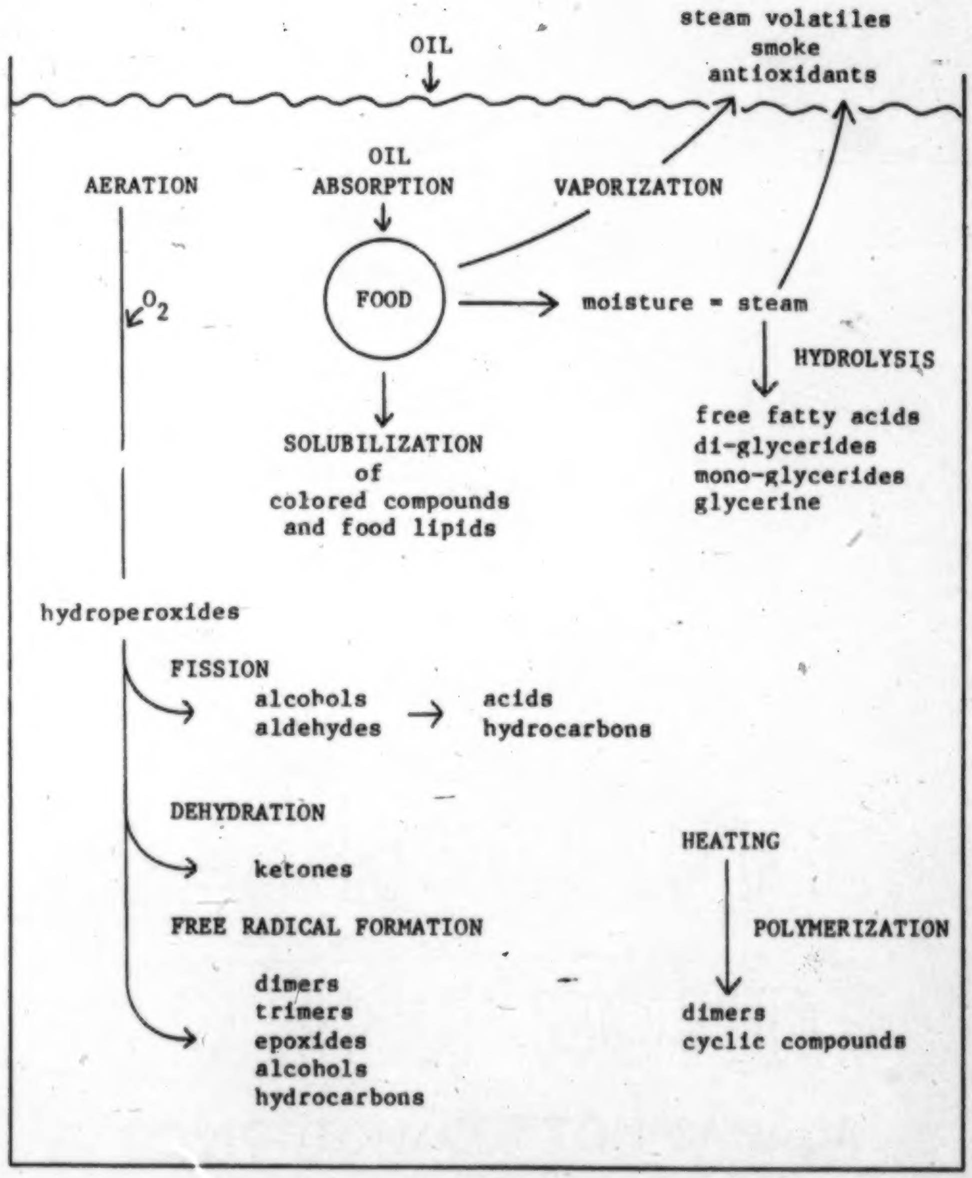


Figure 2. Changes occurring during deep fat frying (adapted from Fritsch, 1981).

Various factors affect the extent to which oil degradation occurs during heating. Temperature of heating (Hess and O'Hare, 1950; Evans et al., 1972; Gere, 1982), duration of heating (Bracco et al., 1981), fat surface exposed to air (Bracco et al., 1981; Gere, 1982), type of fat (Blumenthal et al., 1976), degree of fat unsaturation (Permanyer Fabregas et al., 1986), heating conditions (continuous vs intermittent heating) (Perkins and van Akkerman, 1965; Fritsch et al., 1975; Gere, 1982), presence or absence of food (Krishnamurthy et al., 1965; Perkins and van Akkerman, 1965; Gere, 1982) and amount of food (Thompson and Aust, 1983), affect the degree of degradation in heated fats.

Numerous compounds have been identified from heated fats in which food was fried (Nawar et al., 1978; Chang et al., 1978). Some of these compounds have been found to be harmful to the health of animals (Firestone et al., 1961; Ohfugi et al., 1973; Izaki et al., 1984). Thompson and Aust (1983) concluded that levels of polymers in frying oils were high enough to be of toxicological importance. In deep frying operations, control of the extent to which oil autoxidation and thermal degradation occur is of importance.

An oil treatment which could retard oxidation and inhibit the formation of thermal decomposition products would not only have a health benefit but an economic advantage by extending the use of a frying fat. Andres (1984) has estimated that a 10% increase in the life of frying oils would result in a $500,000/year savings to the fast food industry. In addition, the sensory quality of the oil and products prepared in the oil would be improved.

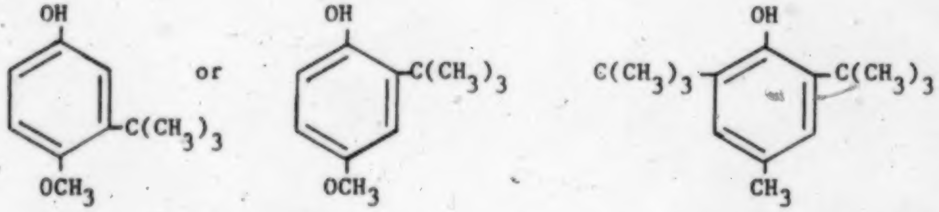
Antioxidants

The addition of antioxidants to vegetable oils has been investigated as a means of increasing the autoxidative and thermal stability of oils. A variety of antioxidants available for use in vegetable oils are shown in Figure 3. Ultimately, the addition of antioxidants to an oil increases the length of the induction period (Gunstone, 1984).

Antioxidants inhibit autoxidation by several modes of action. Phenolic antioxidants, such as butlyated hydroxytoluene (BHT) and butlyated hydroxyanisole (BHA), have a direct effect on the autoxidative process by acting as hydrogen donors and forming relatively stable free radicals and non-radical products (Dugan, 1976; Sherwin, 1976; Sherwin, 1978; Frankel, 1985). This shortens the length of propagation by enchancing the termination step. Antioxidant action can be described as:

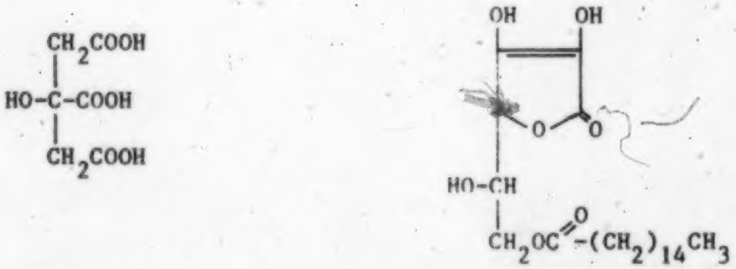
$$R^{\cdot} + AH \longrightarrow RH + A^{\cdot}$$

where $R^{\cdot}$ is the fatty acid free radical and AH is the antioxidant (Frankel, 1985; Sherwin, 1985). Other (ascorbic acid and tocopherols) antioxidants are used in vegetable oils to scavenge oxygen by being preferentially oxidized over the fatty acid (Houlihan and Ho, 1985). Other compounds, such as citric acid (CA), are added to vegetable oils to chelate metals which catalyze the autoxidative process. A number of antioxidants act as synergists. When synergists are used, the oxidative stability achieved is greater than that of an equal weight of a single antioxidant (Dugan, 1976). Synergistic action has been noted between BHA and BHT (Dziezak, 1986) and between tocoperols and ascorbyl



Butylated Hydroxyanisole

Butylated Hydroxytoluene



Citric Acid

Ascorbyl Palmitate

Figure 3. Chemical structure of antioxidants.

palmitate (AP) (Pongracz, 1973). Antioxidant activity is not limited to 1 mode of action, some function in a combination of ways to give effective antioxidative protection.

Antioxidant activity in oils has been shown to differ (Sherwin and Luckadoo, 1970). Ahmad et al. (1983) found that AP, TBHQ, propyl gallate, BHA and BHT had much higher antioxidant activities in crude safflower oil than in a blend of sunflower and cottonseed oils. The oxidative stability of TBHQ treated safflower oil was greater than that of TBHQ treated cottonseed or soybean oils (Sherwin and Thompson, 1967). Thus, studies of antioxidant activity in different oils are needed.

Phenolic antioxidants are generally ineffective in preventing photooxidation due to the reactions which occur. Logani et al. (1983) noted that BHT enhanced the photooxidation of fatty acids. Singlet oxygen quenchers, such as carotene, are effective in inhibiting photooxidation. Recently, Warner and Frankel (1987) investigated the effects of -carotene on the flavor stability of soybean oil exposed to 7535 lux for up to 24 hr. At low levels (5-20 ppm), -carotene significantly reduced flavor deterioration (Warner and Frankel, 1987). Warner and Frankel (1987) also noted that during storage in the dark -carotene did not inhibit flavor deterioration in soybean oil. Thus, -carotene was regarded as an effective singlet oxygen quencher.

During heating and frying antioxidants may escape from the frying medium by volatilization and steam distillation (Fritsch, 1981). Antioxidants may form related breakdown products which might be effective antioxidants themselves (Warner et al., 1986). The decompostion of phenolic antioxidants, such as BHA, BHT and TBHQ, is extensive during deep fat frying (Warner et al., 1986).

Ascorbyl palmitate (Figure 3) is a fat soluble ester of ascorbic acid and palmitic acid. Ascorbyl palmitate is not found in nature. Upon hydrolysis AP forms L-ascorbic acid and palmitic acid, both of which are natural metabolites. Ascorbyl palmitate functions both as an oxygen scavenger and an inhibitor of free radical formation to hamper the autoxidative process (Sedlacek, 1975; Cort, 1974). Ascorbyl palmitate has been shown to act as a powerful synergist with tocopherols (Pongracz, 1973; Klaui, 1976).

Food and Drug Regulations in Canada (Health and Welfare, 1953) do not limit the amount of AP which can be incoporated into vegetable oils; however, at levels greater than 0.05% AP, oils may become cloudy (Pongracz, 1973). If clarity is not important, as in institutional frying, AP can be used in oils at levels as high as 5% (Cort, 1974).

As early as 1947, AP was used to extend the storage stability of vegetable oils. McConnell and Esselen (1947) found that increasing amounts of AP enhanced the accelerated storage stability of corn and cottonseed oils. Pongracz (1973) noted that AP, at increasing concentrations, provided increasing protection to sunflower oil stored at 100°C. In comparing the effectiveness of 0.2% AP, 0.02% BHA and 0.02% propyl gallate in stored (28°C) sunflower and rapeseed oils, Sedlacek (1968) concluded that AP was best for oil stabilization. Cort

(1974) reported that 0.01% AP provided a greater increase in shelf life, as measured by thin layer oxidation at 45°C, than did 0.02% BHA or 0.02% BHT, for safflower, sunflower, peanut, corn and soybean oils. Similar results were noted by Ahmad et al. (1983).

Recent research has shown that AP can effectively extend the life of frying oils. Gwo et al. (1985) heated a partially hydrogenated soybean-cottonseed oil blend with 0.02% AP and found that the addition of AP decreased color development, conjugated diene hydroperoxides and total volatiles. During the frying of French fries, Mancini-Filho et al. (1986) noted that the daily addition of 0.02% AP to a partially hydrogenated soybean oil shortening, reduced the production of free fatty acids but increased color development. Oil darkening during frying was attributed to non-enzymatic browning (Mancini-Filho et al., 1986). Gwo et al. (1985) suggested that even after exposure to high temperatures and long frying times, AP still has the potential to be active as an antioxidant. Published information on the efficacy of AP in stored or heated canola oil is lacking.

Butylated hydroxyanisole and BHT (Figure 3) are 2 of the most commonly used phenolic antioxidants by the food industry. Both BHA and BHT are highly soluble in fats and oils. Butylated hydroxyanisole and BHT inhibit autoxidation by contributing hydrogen from phenolic hydroxyl groups (Sherwin, 1985). Currently in Canada the use of BHA or BHT is limited to 0.02%; however, if used as a BHA/BHT mixture, the total must not exceed 0.02% (Health and Welfare, 1953).

The effects of BHA and BHT on vegetable oil storage stability have been extensively studied. Researchers (Sherwin and Thompson, 1967; Sherwin and Luckadoo, 1970; Ahmad et. al., 1983; Augustin and Berry, 1983a) have noted that BHA, when used alone, was ineffective in retarding autoxidation, as measured chemically. Butylated hydroxytoluene is slightly more effective in retarding autoxidation than BHA (Sherwin and Thompson, 1967; Ahmad et al., 1983; Augustin and Berry, 1983a). Mixtures of BHA and BHT have exhibited a synergistic effect (Dugan, 1976; Dziezak, 1986). However, some workers (Mounts et al., 1978; Rhee, 1978; Vaisey-Genser and Ylimaki, 1985; Hawrysh and Shand, 1986; Hawrysh et al., 1987) have found that addition of BHA and BHT mixtures to stored vegetable oils did little to increase stability. Mounts et al. (1978) stored soybean oils, containing CA with and without BHA/BHT, at 60°C for 8 days. The addition of BHA/BHT did not enhance flavor stability; however, BHA/BHT improved the stability of soybean oil as measured by the active oxygen method (Mounts et al., 1978). In contrast, Rhee (1978) found that addition of BHA/BHT to a stored soybean-cottonseed oil blend gave no improvement in either flavor scores or peroxide values. Similar results for stored canola oils were obtained by Vaisey-Genser and Ylimaki (1985), Hawrysh and Shand (1986) and Hawrysh et al. (1987).

The addition of BHA and BHT to oils used for heating and frying has been relatively ineffective in retarding thermal degradation. In heated palm olein, BHT afforded greater protection than BHA; however, during frying both were ineffective in increasing palm olein stability (Augustin and Berry, 1983b). Both BHA and BHT had no effect on the stability of a soybean-cottonseed oil blend used for frying (Rhee, 1978). Both Vaisey-Genser and Ylimaki (1985) and Hawrysh (1987) noted that the addition of a mixture of BHA, BHT and CA had no effect on the odor scores of heated canola oil. However, Tenox-6, a mixture of BHA, BHT and CA, improved odor scores of soybean oil (Evans et al., 1971).

Although the efficacy of BHA and BHT in protecting vegetable oils from autoxidation and thermal degredation is questionable, BHA and BHT are used to stabilize vegetable oils on the market today. The use of BHA and BHT may be related to the carry-over effect which these antioxidants provide. Both BHA and BHT have provided antioxidative protection for products fried in oils containing these antioxidants (Sherwin and Thompson, 1967; Augustin and Berry, 1984).

Citric acid (Figure 3) is added to vegetable oils to chelate proxidative metals such as iron and copper (Dutton et al., 1948). In 1965, Moser et al. (1965b), evaluated the efficacy of CA in a variety of oils. In all cases, CA addition to oils stored at 60°C for 4 days, significantly improved flavor scores (Moser et al., 1965b). Citric acid is generally used in combination with antioxidants in vegetable oils and has been reported act synergistically with BHA and BHT in stored oils (Cowan et al., 1962; Sherwin, 1978; Ahmad et al., 1983; Dziezak, 1986). Since CA decomposes at frying temperatures, CA will not provide any protection once an oil is heated (Frankel, 1980b). The Canadian Food and Drug Regulations do not limit CA use in fats and oils (Health and Welfare, 1953). Good manufacturing practice is expected. In a study of the efficacy of CA in soybean oil, Dutton et al. (1949) found that levels above 0.01% did not enhance oxidative stability.

In an effort to improve the shelf-life and thermal stability of fats and oils, antioxidants may be added during processing. Many antioxidants are available for use in fats and oils, each with its own level of activity in delaying autoxidation, photooxidation and thermal degradation. Although most vegetable oils contain some natural antioxidants, the levels present are generally not sufficient to provide protection from oxidative processes. There is a need for studies of the efficacy of natural antioxidants in extending canola oil stability.

Methods of Evaluating Oil Stability

To determine antioxidant efficacy, numerous techniques have been developed for the evaluation of autoxidation and photooxidation and the measurement of the storage stability of fats and oils. Chemical, sensory and instrumental techniques are used to determine the extent of autoxidative, photooxidative and thermal degradation in oils. Sensory evaluations of the odor and flavor characteristics of oils have been benefical and effective in assessing oil quality.

Accelerated and practical storage tests are used to monitor oil storage stability. Since the assessment of antioxidants under diverse storage conditions gives differing findings (McConnell and Esselen, 1947; Moser et al., 1965b; Ragnarsson et al., 1977; Kiritsakis et al., 1983; Dziedizic and Hudson, 1984), the storage stability of fats and oils should be measured under a variety of conditions.

Vegetable oils are widely used for deep fat frying and pan frying. A recent consumer survey (Shaykewich and Vaisey-Genser, 1982) noted that oil was the most popular fat for pan and deep fat frying among western Canadian consumers. Shaykewich and Vaisey-Genser (1982) found that 89% of the households surveyed pan fried foods and 42% deep fried foods. Research on oil degradation during deep fat frying has been reported (Rock and Roth, 1964; Dornseifer et al., 1965; Krishnamurthy et al., 1965; Perkins and Van Akkerman, 1965; Freeman et al., 1973; Blumenthal et al., 1976; Yuki and Ishikawa, 1976; Fritsch et al., 1975; Bracco et al., 1981; Gere, 1982; Peers and Swoboda, 1983; Stevenson et al., 1984a; Thompson and Aust, 1984; Frankel et al., 1985; Gwo et al., 1985; Yoon et al., 1985; Mancini-Filho et al., 1986; Yoon et al, 1987). However, studies of the effects of pan frying on oil deterioration are lacking.

Storage and Thermal Stability Tests

Accelerated storage tests are often used to assess the stability of a fat or an oil. The Schaal oven test (Joyner and McIntyre, 1938), involves storing oil samples at 60° to 65°C for a specified number of days. Four days of storage at 60°C has been estimated to be roughly equivalent to 3 months storage at room temperature (Evans et al., 1973). The Schaal oven test has been employed to evaluate the efficacy of antioxidants in extending the shelf life of vegetable oils (List et al., 1972; Mounts et al., 1978; Mounts et al., 1981; Min and Wen, 1983; Hawrysh and Shand, 1986).

The adverse effects of light on oil stability have been well documented (McConnell and Esselen, 1947; Moser et al., 1965a; Sattar et al., 1976; Frankel, 1985; Kiritsakis and Dugan, 1985; Hawrysh et al., 1987). Moser et al. (1965a) developed a fluorescent light test as a means of accelerating the oxidative process. On the basis of peroxide value determinations, Moser et al. (1965a) found that exposure of soybean oil to 7532 lux of light intensity for 1 hr was equivalent to 4 days storage at 60°C. The fluorescent light test has been used to measure the flavor stability of a variety of vegetable oils, with and without antioxidants (Dupuy et al., 1977, Mounts et al., 1978; Warner et al., 1978; Yoon et al., 1985; Hawrysh and Shand, 1986), as well as to evaluate the efficacy of different packaging (Warner and Mounts, 1984).

Practical storage tests, during which oil is stored at room temperature, under varying light and packaging conditions, for a specified period of time, have also been used to assess the flavor and oxidative stability of vegetable oils (Paul and Roylance, 1962; Luckadoo and Sherwin, 1972; Evans et al., 1973; Morrison et al., 1981; Augustin and Berry, 1983a; Kiritsakis et al., 1983; Hawrysh et al, 1987). Paul and Roylance (1962) compared the use of 2 accelerated storage tests, the Swift Stability Test and the measurement of oxygen absorption, with storage at room temperature, to evaluate antioxidant efficacy. They (Paul and Roylance, 1962) concluded that only storage at room temperature gave a true assessment of the value of an antioxidant in edible oils. The major drawback of storing oils under practical conditions (at room temperature), is the long time period involved. Storage times of up to 3 years have been used (Hung and Slinger, 1981).

The thermal stability of vegetable oils has been extensively researched under deep fat frying and heating conditions. Methods for evaluation range from static heating, in a variety of containers, to elaborate frying procedures. However, there do not appear to be standard methods for assessing the thermal stability of vegetable oils. Recently, Snyder et al. (1986) reported that static heating of small quantities of oil at 190°C for 1 hr in the presence of air, provided an accelerated thermal oxidation test. Evaluations of the room odor, which develops during the heating of high C18:3 oils, have been used to assess antioxidant efficacy in frying fats (Evans et al., 1971; Evans et al., 1972; Warner et al., 1985; Frankel et al., 1985). However, room odor tests have not been adopted by the edible oil industry for assessing the thermal stability of oils (Mounts and Warner, 1980).

Evaluations of oil stability are important in ensuring product quality. Accelerated (Schaal oven, fluorescent light) and shelf (practical) storage tests are commonly used to assess storage stability and antioxidant efficacy in oils. Evaluation of thermal stability is important to ensure the quality of frying fats and oils, as well as that of the final cooked product. Since the extent of oil degradation during heating depends on conditions of use, careful interpretation and application of results is necessary.

Chemical and Instrumental Measurements

Since hydroperoxide development in oils is a preliminary step in the autoxidative process, peroxide values (PV) can be used as an indicator of primary oxidation. The degree of autoxidation is determined by the amount of iodine a fat can liberate from potassium iodide and is expressed as milliequivalents of iodine formed per kilogram of fat (AOCS, 1979. Method Cd 8-53). The PV of a freshly refined oil should be less than 1 meq/kg (Rossell, 1986). Peroxides breakdown readily during storage and heating; therefore, PV alone may not always indicate the extent of oil deterioration.

Numerous studies have shown a high correlation between PV and sensory flavor scores of stored oils (Fioriti, et al., 1974; Eskin and Frenkel, 1976; Mounts et al., 1978; Vaisey-Genser and Ylimaki, 1985; Hawrysh and Shand, 1986). However, in studies of antioxidant efficacy Mounts et al. (1981) and Moulton et al. (1985) found little agreement between flavor scores and PV. Sattar et al. (1976) noted a strong relationship between PV and flavor scores for low erucic acid rapeseed, corn and soybean oils, exposed to fluorescent light. Sattar et al. (1976) reported that the PV at which an oil was unacceptable, differed for various vegetable oils. For example, rapeseed oil with a PV of 12.9 had a slight oxidized flavor and was still acceptable; however, soybean oil with a PV of 2 was unacceptable (Sattar et al., 1976). Because peroxides are very unstable during heating, PV are not recommended for measuring frying fat deterioration (Fritsch, 1981).

The thiobarbituric acid (TBA) test is commonly used to indicate oil quality (Gray, 1985). The reagent, 2-thiobarbituric acid, reacts with malonaldehyde, a secondary oxidation product in a fat or oil, to form a reddish-orange pigment. Generally, TBA number is determined by measuring the absorbance of the reddish-orange pigment at 532 nm (Gray, 1978). Jacobson et al. (1964) observed that saturated and monounsaturated aldehydes react with TBA to give a yellow color absorbing at 452 nm and that diunsaturated aldehydes react to give a pink color absorbing at 532 nm. However, Patton (1974) has questioned the value of measuring the absorbance at 450 nm, since this absorbance may be produced by the reaction of TBA with aldehydes which are not necessarily oxidation products. According to Patton (1974) the absorbance at 450 nm may not be a true assessment of lipid rancidity. However, Erdelyi (1983) has suggested that the TBA absorbance at 450 nm is more sensitive and reliable than that at 530 nm.

Reports of correlations between TBA values and sensory scores for various oils, have resulted in conflicting conclusions. Eskin and Frenkel (1976) evaluated the stability of rapeseed oil, stored at 60°C for up to 16 days, and found that TBA numbers, at 528 nm, showed excellent correlations with PV and with odor intensity scores. Fioriti et al. (1974) reported poor correlations between TBA numbers, as measured at both 450 and 532 nm, and flavor scores of hydrogenated soybean oil, high oleic safflower oil and corn oil stored at 37°C. In contrast, Fioriti et al. (1974) also noted good correlations between TBA numbers and flavor scores for the same oils stored at 60°C. Fioriti et al. (1974) concluded that the TBA test is of limited value in measuring the extent of oxidized flavors in fats. Kiritsakis and Dugan (1985) found that TBA values were helpful in examining olive oil photo-oxidation. However, Hawrysh and Shand (1986) noted that TBA numbers, at 532 nm, produced only fair correlations with odor intensity scores for canola oil exposed to fluorescent light.

Conjugated diene hydroperoxides (CD) and conjugated triene hydroperoxides (CT) are fast methods of assessing the degree of oil oxidation (Gray, 1985). Unsaturated fatty acid oxidation is associated with an increase in ultraviolet absorption, which when measured at 234 nm indicates the presence of primary oxidation products, specifically linoleic acid hydroperoxides and conjugated dienes. The absorbance measured at 268 nm denotes the presence of secondary oxidation products and conjugated trienes (IUPAC, 1978). Conjugated diene and CT determinations have been used to evaluate both storage and heat stability of oils. However, both CD and CT are more commonly used to determine oil heat stability. Augustin and Berry (1983a) measured the CD and CT content of antioxidant treated refined, bleached and deodorized palm olein stored at 60°C for up to 68 days. They noted that CD increased steadily during storage time; however, changes in CT were small. Changes occurring in heated fats and oils are reflected by increases in absorbance at 234 and 268 nm (Gere, 1982; Augustin and Berry, 1983b).

p-Anisidine values (AV) have been used to indicate secondary oxidation products, specifically aldehydic compounds (IUPAC, 1978). In the presence of acetic acid, p-anisidine reacts with aldehydic compounds in oils to form a yellowish reaction product. The intensity of the yellow color formed depends not only on the presence of aldehydic compounds, but also on their structure (IUPAC, 1978). Generally, the AV of a freshly refined vegetable oil should be below 10 (Rossell, 1986). List et al. (1974) reported a significant correlation between the AV of salad oils from undamaged soybeans and their flavor scores. Soybean oils stored at 60°C up to 10 days, or exposed to fluorescent light for up to 16 hr, showed little change in AV (List et al., 1974). In heated palm olein, Augustin and Berry (1983b) found that AV increased markedly on the first day of heating, followed by small changes on the second day and subsequent days of heating.

Dark color development in oil during heating has been attributed to the absorption of energy from the visible light spectrum by carotenoid pigments present in the oil (Gwo et al., 1985). Polymerization of NVDP also results in oil darkening (Stevenson et al., 1984b). Color development in an oil can be assessed by measuring oil absorbance at 363 nm (Gwo et al., 1985).

The free fatty acid (FFA) content of an oil is a measure of the extent to which hydrolysis has liberated fatty acids from their ester linkage with the parent glyceride molecule (Rossell, 1986). Analysis of the percentage of FFA has been suggested as the method of choice for determining frying fat deterioration (Zabik, 1962; Stevenson et al., 1984a). Others (Fritsch, 1981; Croon et al., 1986) have concluded that FFA analysis is a poor measure of frying fat deterioration.

The smoke point of an oil is the temperature at which a fat will begin to give off a continuous wisp of smoke (AOCS, 1979. Method Cc 9a-48). Canadian Government specifications require that frying oils have a smoke point above 200°C (Vaisey-Genser and Eskin, 1982). In the Federal Republic of Germany, an oil with a smoke point below 170°C is considered unsuitable for consumption (Billek et al., 1978). Smoke point determinations are used as an index of frying oil deterioration.

Stevenson et al. (1984a) noted a correlation of -0.90 between the smoke point of a slightly hydrogenated canola oil and hours of frying.

Oil viscosity, an index of its flow properties, varies among different vegetable oils (Vaisey-Genser and Eskin, 1982). During heating, oil viscosity increases as a result of polymerization. Viscosity measurements of canola and soybean oils have shown excellent correlations with hours of frying (Stevenson et al., 1984a).

The detection and quantification of oil volatiles by gas liquid chromatography (GLC) is one of the more recently developed methods of evaluating flavor and oxidative stability of oils (Min, 1981). Researchers (Scholz and Ptak, 1966; Evans et al., 1969; Fioriti et al., 1974; Warner et al., 1974; Dupuy et al., 1976; Dupuy et al., 1977; Jackson and Giacherio 1977; Waltking and Zmachinski, 1977; Williams and Applewhite, 1977; Morrison et al., 1981; Warner and Frankel, 1985) have used GLC to assess the oxidative state of an oil and have found good correlations between flavor scores and specific volatiles. Scholz and Ptak (1966), Evans et al. (1969), Fioriti et al. (1974), Warner et al. (1974), Morrison et al (1981) and Warner and Frankel (1985) noted good correlations between pentane, as measured by GLC, and flavor scores. Dupuy et al. (1977) found that trans-2, trans-4 decadienal gave the most sensitive and accurate correlations with flavor scores. Studies correlating total volatiles with flavor scores have also reported good results (Dupuy et al., 1976; Jackson and Giacherio 1977; Waltking and Zmachinski, 1977; Williams and Applewhite, 1977).

The use of GLC for evaluations of the efficacy of antioxidants in improving the flavor and oxidative stability of oil has been investigated. Warner et al. (1978) found that the addition of CA and TBHQ reduced the amount of hexanal and pentanal formed in soybean oil stored for up to 16 days at 60°C. Good correlations between hexanal and pentanal and flavor scores of soybean oil were obtained (Warner et al., 1978). However, with the addition of antioxidants to cottonseed and peanut oils, correlations between pentanal and flavor scores could not be established (Warner et al., 1978). Morrison et al. (1981), in a study of the correlation of GLC volatiles (pentane) and flavor intensity scores of antioxidant treated sunflower oils, reported a correlation coefficient of 0.65. In canola oil stored at room temperature for up to 16 weeks, Tokarska et al. (1986) concluded that the addition of TBHQ, at levels as low as 100 ppm, had a substantial effect in retarding oxidative changes as measured by GLC.

Chemical and physical measurements are useful in assessing oil stability during storage and heating. The complexity of oxidative and thermal decompostion reactions in oils necessitates the use of a variety of tests, each of which monitors one or more of the changes which occur. Some of the currently available chemical methods of assessing oil quality have yet to be employed to monitor changes in canola oil. Thus physico-chemical evaluations of canola oil stability during storage and heating are warranted.

Sensory Evaluation

Sensory evaluation of the odor and flavor quality of vegetable oils is considered to be the ultimate method of assessing oil quality (Warner and Frankel, 1985). Since chemical and instrumental procedures, as outlined earlier, lack the ability to integrate taste and smell into an overall impression, sensory panels are required to evaluate oil quality (Warner, 1985). A highly trained descriptive panel can be used as an analytical tool to evaluate the sensory quality of oils (IFT, 1981).

Basic sensory principles require that testing be done under controlled conditions (Larmond, 1977). Quiet, comfortable, and odor free surroundings, where panelists can make independent judgements, are miniumun requirements (ASTM, 1968). Temperature, humidity and light conditions should also be controlled (Mounts and Warner, 1980).

The selection and training of panel members is critical to their performance as an analytical tool. Cross et al. (1978) outlined panel selection and training techniques, for the sensory analysis of meat quality, which have been applied to the selection and training of panels for the evaluation of oil quality (Hawrysh et al., 1987). Cross et al. (1978) identified 3 objectives of training: (1) to familiarize the panelist with test procedures, (2) to improve a panelist's ability to recognize and identify sensory attributes and (3) to improve a panelist's sensitivity and memory. During training panelists should evaluate samples of varying quality or intensity (Warner, 1985).

The most efficient use of a sensory panel can be obtained by evaluating the maximum number of samples at each session (Mounts and Warner, 1980). Moser et al. (1950) noted that panelists thought that the evaluation of 6 oil samples at a session resulted in fatigue; but, up to 10 samples per session have been evaluated (Fioriti et al., 1974).

In 1950, Moser et al. described a method for evaluating the sensory characteristics of edible oils, the basic principles of which are still in use today. Since odors and flavors can be more readily detected in a warm sample, Moser et al. (1950) proposed an oil temperature of 55°C for evaluation. Researchers have used oil sample temperatures ranging from 50°C to 60°C for sensory assessments (Fioriti et al., 1974; Waltking and Zmachinski, 1977, Morrison et al., 1981; Warner and Frankel, 1985).

Generally, oil evaluations are made without dilution (Evans, 1955). Recently Stone and Hammond (1983) proposed a method of evaluating oils as emulsions. However, the results obtained using emulsions differed from those for oils. After storage of soybean oil, for 5 days at 55°C, flavor scores for oils were significantly more intense than those for emulsions (Stone and Hammond, 1983). Preliminary oil evaluations were conducted in the Department of Foods and Nutrition, University of Alberta, using Stone and Hammonds' (1983) emulsion method for oil assessment. Panelists found that tasting emulsions was no more palatable than tasting oils.

The sensory characteristics of concern in oils are the overall odor and flavor intensity and the strength of individual odor and flavor notes. Descriptive analysis is employed to assess the sensory characteristics of oil. Descriptive analysis requires the use of a rating scale for quantification. Two variations of a 10-point category scale have been adopted by the American Oil Chemists' Society (AOCS) for the sensory evaluation of oils (Warner, 1985). However, a variety of different scales are used by oil researchers.

The AOCS flavor quality scale requires panelists to score an oil sample on a 10-point scale where 10=bland or excellent, 5=poor with raw, reverted, rubbery, watermelon, or bitter flavors, and 1=repulsive. This scale requires a very well trained panel, as all panelists must use the same descriptors for specific notes or meaningless scores will be obtained (Warner, 1985). Perhaps the difficulty with the AOCS flavor quality scale is that it uses a linear scale for non-linear attributes. This scale is not commonly used for research purposes.

The AOCS intensity scale is more commonly used. The AOCS intensity scale involves rating the overall odor or flavor intensity of an oil sample on a 10-point scale, where 10=bland and 1=extreme, as well as rating the strength of individual odor or flavor notes as either weak, moderate or strong (Warner, 1985). In some instances researchers (Hawrysh and Shand, 1986; Hawrysh et al., 1987) have converted the weak to strong verbal scale, for rating odor and flavor note strength, to a 4-point numerical scale, where 0=not present and 3=strong. Other scales, such as a semi-structured line scale (Eskin and Frenkel, 1976; Dobbs et al., 1978, Vaisey-Genser and Ylimaki, 1985), a 9-point "off flavor" scale (Fioriti et al., 1974), a 7-point intensity scale (Phole et al, 1964), a 6-point rancidity scale (Scholz and Ptak, 1966) and a 5-point rancidity scale (Jarvi et al., 1971; Morrison et al., 1981), have been used to assess oil quality.

Although the practice of using trained analytical taste panels for the evaluation of hedonics (like/dislike, unpleasantness) is not considered to be appropriate (Pangborn, 1980), oil researchers have used trained panels for the evaluation of oil pleasantness. Blumenthal et al. (1976) and Waltking and Zmachinski (1977) employed trained panels to evaluate odor and flavor strength on a 9-point intensity scale, as well as to assess the pleasantness of the sample on a 9-point scale ranging from 1=very pleasant, 5=neutral to 9=very unpleasant.

Evaluations of individual odor and flavor notes are important to the overall assessment of oil quality, as oils under different conditions develop a variety of odor and flavor notes. After 4 days of storage at 60°C, Moser et al. (1965b) found that crambe oil was more painty than soybean, mustard or rapeseed oils. Moser et al. (1965a) noted that exposure of soybean, cottonseed and safflower oils to fluorescent light, resulted in the development of a pronounced grassy flavor. Hawrysh et al. (1987) reported that the addition of either a combination of BHA, BHT and CA, or TBHQ to canola oil, stored at room temperature for up to 16 weeks, resulted in higher grassy and fishy odor and flavor intensity values than those obtained for a control without antioxidant.

Sensory evaluation is used as an analytical tool in assessing the oxidative state of an oil. Sensory panels integrate the odor and flavor characteristics of oil to monitor the changes which occur during storage and heating. Supported by chemical data, sensory analyses is the final judgement oil quality (Jackson, 1981). Trained panel evaluations of antioxidant treated canola oils are limited and more research is needed.

3. EXPERIMENTAL METHODS

Experimental Design and Statistical Analysis

Six experiments were carried out, 3 to evaluate storage stability and 3 to evaluate thermal stability of antioxidant treated canola oil. Table 2 summarizes the experiments conducted. Evaluations of oil quality included sensory, chemical and physical measurements.

A strip-plot experimental design (Milliken and Johnson, 1984), involving treatments and storage/heating, was used for each experiment. Data for all measurements were subjected to the analyses of variance outlined by Milliken and Johnson (1984). Sources of variation consisted of treatments (n=5 for chemical and instrumental tests; n=6 for sensory tests), storage or heating times (n=3, 4 or 5); replications (n=2 or 3) and for taste panel data, panelists (n=7 or 8). Student-Newman-Keuls' Multiple Range test (Steele and Torrie, 1980) was used to identify significant differences among treatment means.

Within each experiment correlation analyses were performed to assess the relationships between appropriate sensory (odor and flavor intensity) and chemical/instrumental data.

Materials Used for the Study

Fresh, fully refined, bleached, deodorized canola oil, containing no antioxidants, was obtained in three lots from Canbra Foods, Lethbridge,

Table 2. Summary of laboratory experiments[1].

Experiment	Replications	Storage or Heating Times	Total Experimental Samples
Schaal Oven Storage	3	0, 4, 8, 12, 16 days	75
Fluorescent Storage	3	0, 8, 16, 24 hours	60
Practical Storage	3	0, 5, 10 months	45
Extended Heating	3 2	1, 2.5, 5 days 10 days	55
Deep Fat Heating	3	0, 20, 40, 60 minutes	60
Shallow Pan Heating	3	0, 6, 12 minutes	45

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[1] All experiments involved 5 oil treatments (T1-T5) as listed in Table 3.

Alberta. The phenolic antioxidants, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) and citric acid (CA), as monoglyceride citrate (20% citric acid), were obtained from Griffith Labs, Scarborough, Ontario. Ascorbyl palmitate (AP) was obtained from Hoffman-LaRoche, Etobicoke, Ontario. Polyvinyl chloride (PVC) bottles for practical oil storage studies were obtained from Proctor and Gamble Inc., Toronto, Ontario.

Antioxidant Incorporation

For each replicate of each storage and heating experiment a separate batch of each oil treatment was mixed except where otherwise noted. For each replication the order of mixing of oil treatments was randomized.

For each experiment canola oil was subjected to each of 5 treatments (T1-T5) outlined in Table 3. Butylated hydroxyanisole, BHT and CA were added to the oil neat, which is typical of current industrial practice. Because of solubility problems, AP was added to the oil as a 5% solution in ethanol. A 10% solution in ethanol is recommended by Hoffman-LaRoche (Hoffman-LaRoche, 1985), however AP precipitated after 1 hr at room temperature. The amounts of antioxidant treated oils prepared varied among experiments, depending on requirements and will be detailed later.

For each treatment, the oil was heated to 80°C and the antioxidants were incorporated. The oil was held at 80°C and stirred on a hotplate (Fisher 310T Stirring Hotplate) for 30 min. The oil was then transferred to a hotplate at room temperature and stirred for an

Table 3. Canola oil treatments.

Treatment Number	Canola Oil Treatment
T1	no antioxidant - control
T2	BHA/BHT (100 ppm each) CA (50 ppm)
T3	AP (100 ppm)
T4	AP (200 ppm)
T5	AP (200 ppm) CA (50 ppm)
T6	Hidden Control (for sensory analyses only)

additional 30 min. The oil was portioned either into beakers for immediate use, or into 500 or 1000 ml amber glass bottles, flushed with nitrogen and either held overnight at 5°C for use the following day or immediately frozen (-25°C) for later use.

During mixing, reference samples of fresh canola oil were removed for sensory and chemical use. These were placed in 20 ml vials, flushed with nitrogen and frozen at -25°C for later use. At the designated storage and heating times (Table 2) samples were placed in appropriate glass vials or bottles, flushed with nitrogen and held (-25°C).

All glassware used was washed with alcoholic potassium hydroxide, dilute hydrochloric acid and glass distilled water to prevent contamination (Morrison et al., 1981).

Accelerated Storage

Canola oil treatments for the 2 accelerated storage tests, Schaal oven storage and fluorescent light storage, were mixed in 1000 g batches as described and held over night.

For the Schaal oven test, 4 samples of each oil treatment (68 g) were placed in 100 ml pyrex beakers, covered loosely with aluminum foil lids and held in a forced air oven at 65°C for up to 16 days. Oil samples were removed at 0, 4, 8, 12 and 16 days.

Three replicates of the Schaal oven test were completed simultaneously, by randomly assigning each shelf in the oven to 1 replicate. The placement of samples on the shelves was randomized across oil treatment by time combinations.

For fluorescent light storage, 3 samples (68 g) of each oil treatment were placed in 150 x 15 mm plastic petri dishes and exposed to light (7532 ± 750 lux) from daylight fluorescent tubes for up to 24 hr at room temperature. Samples were removed at 0, 8, 16 and 24 hr.

Three replications of the experiment were completed on consecutive days. The placement of samples under the lights was randomized across oil treatment by time combinations.

Practical Storage

Canola oil treatments for practical storage were stored in 1000 ml PVC bottles for up to 10 months. For storage in PVC bottles, each oil treatment was mixed in two 1000 g batches for each of 3 replications (a total of 6 batches, 2 per replication). The first oil mix of each replicate was designated for 5 months storage, the second for 10 months storage. Each of 2 PVC bottles was filled with 900 g of canola oil.

Oil treatments were subjected to fluorescent light (1400 ± 107 lux) for 12 hr/day for either 5 or 10 months during storage at room temperature (23°C). Appropriate samples were removed to represent 0 time.

Three replicates of the practical storage experiment were completed simultaneously. Each replication was randomly assigned to a section of the storage shelf. Oil treatment by time combinations were randomized within a replication for placement.

Heating Studies

Prior to the commencement of the heating experiments, all household electric stove elements to be used were monitored to ensure that comparable heating rates were achieved. Mercury thermometers, which had been standardized against an ASTM thermometer, were used to monitor oil temperatures for the extended and deep fat heating experiments. Oil treatments for extended heating were prepared the day prior to the beginning of each replicate and held either at 5°C or room temperature overnight. For deep fat and shallow pan heating experiments, oil treatments were prepared the day prior to the beginning of each replicate and held at 5°C overnight.

Extended Heating

For extended heating, each oil treatment was mixed in two 1000 g batches per replication. A total of 3 or 4 samples (450 g) of each oil treatment was portioned into 1000 ml heavy duty pyrex beakers and heated on household electric stove elements. The surface of the oil exposed to air was 85 cm^2 and the oil specific surface was 0.189 cm^2/g, which was similar to that used by Gwo et al. (1985). Each oil treatment was individually heated to 180°C and held at 185 ± 5°C for 10 hr per day for up to 10 days. Oil temperatures during heating were recorded every hour. Samples were taken for evaluation at 1, 2.5, 5 and 10 days. At the end of each daily 10 hr period, the beakers of oil were removed from the elements, allowed to cool 1 hr and covered with aluminum foil. Overnight storage of oils was at room temperature.

Three replications of the 1, 2.5 and 5 days heating and 2 replications of 10 days heating were completed. Replicates were completed consecutively with some overlap so that heating times within a replication had a common start or common end point. For assignment to heating elements, oil treatment by time combinations were randomized within a replication.

Deep Fat Heating

Each oil treatment for deep fat heating was mixed in 2 batches (1000 g) per replication, with half of mix 1 designated for 0 min and the other for 20 min. Mix 2 was used for 40 and 60 min of heating. Four samples (450 g) of each treatment were held in 1000 ml heavy duty pyrex beakers (specific surface 0.189 cm^2/g) and heated on household electric stove elements. Each canola oil sample was individually heated to 185°C and held at 185 ± 5°C for up to 60 min. Oil temperatures were recorded every 10 min. Samples were removed for evaluation at 0, 20, 40 and 60 min at 185 ± 5°C.

Three replicates were completed on consecutive days. Oil treatment by time combinations were randomized within a replication for assignment to heating elements. A total of 20 treatment by time combinations were completed in 1 day in 2 "heating runs" using 10 elements.

Shallow Pan Heating

For shallow pan heating, each oil treatment was mixed in one 1500 g batch per replication. Samples (150 g) of each canola oil treatment were indivdually heated, in 1 of 3 stainless steel frying pans on 1 of 3 household stove elements, to 185°C and held at 185 ± 5°C for 0, 6 and 12 min. The surface of the oil exposed to air was 433.7 cm^2 and the oil specific surface was 2.89 cm^2/g. Oil temperature was monitored with a Bailey's Digital Thermometer (Model BAT 8). For each oil treatment by time combination within a replication, 3 heating trials, of 150 g each, on each of 3 heating elements, were necessary to obtain the oil (450 g) required for analysis. The 3 heating trials for each treatment by time combination were completed consecutively with the oil from each mixed to represent one replication.

Shallow pan heating was replicated 3 times. Each replication was completed over 3 days with 5 randomly selected oil treatment by time combinations being completed each day (a total of 15 heating trials per day). Replications were completed consecutively, with oil being mixed the day prior to the first day of heating for that replication.

Objective Measurements

Chemical

The initial chemical properties defined for the fresh canola oils were iodine value (IV), peroxide value (PV), and fatty acid composition. Samples exposed to storage conditions (accelerated and practical) were subjected to analysis of PV, conjugated diene and conjugated triene hydroperoxides (CD and CT, respectively) and thiobarbituic acid values (TBA). Chemical analysis of samples exposed to heating conditions (extended, deep fat, and shallow pan) included determinations of PV, CD, CT, p-anisidine value (AV), color, and free fatty acids (FFA). Stored and heated oil samples, representing each oil treatment from each replicate, were analyzed in duplicate.

Iodine Value

Iodine values were determined by the Wijs method (IUPAC, 1978). An oil sample (0.2 g) was weighed into a 250 ml Erlenmeyer flask, to which 15 ml carbon tetrachloride and 25 ml Wijs solution were added. The flask was stored in the dark for 1 hr. The excess halogen was determined by addition of 20 ml potassium iodide aqueous solution (100 g/l) and 150 ml distilled water, which was followed by titration of the liberated iodine with a standardized sodium thiosulphate solution (0.1 N). The IV, which is the number of grams of halogen absorbed by 100 g of the oil, was expressed as the weight of the iodine.

Peroxide Value

Peroxide values were determined using AOCS Official Method Cd 8-53 (AOCS, 1979). An oil sample (5 g) was weighed into a 250 ml Erlenmeyer flask, dissolved in 30 ml glacial acetic acid-chloroform mixture (3:2 v/v) and then treated with 0.5 ml saturated potassium iodide. The solution was allowed to stand with occasional shaking for exactly 1 min and then 30 ml water was added. The liberated iodine was titrated with sodium thiosulphate solution (0.01-0.005 N) in the presence of a starch indicator solution (1%). Peroxide values were expressed as milliequivalents of peroxide per 1000 g of sample.

Fatty Acid Composition

The fatty acid composition of the fresh oils was determined after transesterification with boron trifluoride methanol reagent (Morrison and Smith, 1964). A Varian Vista 3700 gas liquid chromatograph, equipped with a flame ionization detector and Hewlett Packard 335 chromatography data system, was used. The samples were injected into a 30 meter (ID 0.25 mm) fused silica capillary column (Supelco Inc.). The gas chromatograph was operated with a nitrogen carrier gas at a flow rate of 1 ml/min. Detector flow rates for the gases were: 30 ml/min for hydrogen and 300 ml/min for compressed air. The injector and detector temperatures were 220°C. The column oven temperature was held at 180°C for one min, then increased to 220°C at a rate of 5°C/min and held at this temperature for 20 min. Compounds were identified by comparing their retention times with those of known standards.

Conjugated Dienes and Trienes

Conjugated diene and conjugated triene hydroperoxide contents of the samples were determined using the IUPAC method (IUPAC, 1978). An oil sample (0.100 g) was weighed into a 10 ml volumetric flask and diluted to the mark with hexanes. A sample (0.1 to 1 ml) of this was transferred to a test tube, diluted to 10 ml with hexanes and mixed briefly. The absorbance of the solution in quartz cells was measured using a Unicam SP 1800 ultraviolet spectrophotometer at 234 and 268 nm to represent CD and CT contents, respectively.

Thiobarbituic Acid Value

Thiobarbituic acid values were determined by the procedure described by Fioriti et al. (1974) and modified by Erdelyi (1983). The oil sample (0.12 g) was dissolved in 2 ml 50% (v/v) absolute alcohol in 2,2,4-trimethylpentane in 25 x 150 mm culture tubes with teflon caps. To this solution 5.0 ml trimethylpentane and 3.0 ml thiobarbituric acid solution (0.33 g TBA in 10 ml distilled water and 90 ml isopropyl alcohol) were added. The capped tubes were shaken vigorously for 30 sec and incubated in a water bath at 60°C for 1 hr. The absorbance of the solution (against an equivalent blank) was read at both 452 and 532 nm with a Unicam SP 1800 ultraviolet spectrophotometer.

p-Anisidine Value

p-Anisidine values were determined using the IUPAC method (IUPAC, 1978). An oil sample (0.5 to 4.0 g) was weighed into a 25 ml volumetric flask and diluted to the mark with iso-octane. The absorbance of this solution, measured at 350 nm using a Unicam SP 1800 ultraviolet spectrophotometer, with iso-octane as a blank, was used as the blank for the calculation of the AV. Samples (5 ml) of the oil solution and iso-octane were then pipetted into separate test tubes, 1 ml of p-anisidine solution was added to each tube and the tubes were mixed. After exactly 10 min the absorbance of the oil/p-anisidine solution was measured at 350 nm with the iso-octane/p-anisidine solution as a blank in the reference cell.

Color

Color was determined by the method described by Gwo et al. (1985). An oil sample (0.100 ± 0.005 g) was weighed into a 10 ml volumetric flask and diluted to the mark with hexanes. After the oil was completely dissolved, the absorbance was read against a hexane blank at 363 nm using a Unicam SP 1800 ultraviolet spectrophotometer.

Free Fatty Acids

Free fatty acids were determined using the method described by Ke and Woyewoda (1978). An oil sample (1.00 or 20 g) was weighed into a 250 ml Erlenmeyer flask to which 75 ml of a chloroform/2-propanol/methanol (2:2:1 v/v/v) solution and 4 drops of meta-cresol purple indicator were added. The solution was then titrated with standardized sodium hydroxide solution (0.05 N). The %FFA were expressed as equivalents of oleic acid.

Instrumental

Instrumental analyses of the heated oil samples, measured in triplicate, included determinations of viscosity and smoke point.

Viscosity

Viscosity was measured using a Brookfield viscometer (Model RVTD) with the UL sample adapter at 25°C. An oil sample (16 ml) was placed into the UL sample adapter, which was then attached to the viscometer and the viscosity was measured. The speed at which the viscosity was measured varied from 10 to 50 RPM for extended heating. The viscosity of samples from 1 and 2.5 days of heating were measured at 50 RPM; 5 days at 20 RPM; and 10 days at 10 RPM. For deep fat and shallow pan heating viscosity was measured at a speed of 100 RPM.

Smoke Point

Smoke points were determined according to the standard method (Official Method Cd 9a-48) of the AOCS (AOCS, 1979). A brass Cleveland open flash cup, ASTM designation D92-33, was filled with oil to the filling line and placed on a Fisher/Cleveland Flash point open tester, a beam of light from a 100W daylight bulb was directed across the centre of the cup. The oil sample was heated rapidly to within 40°C of the expected smoke point, as determined during preliminary work. The sample was then heated at a rate of 5 to 6°C per min. The smoke point was the temperature at which the oil sample gave off a thin continuous stream of bluish smoke.

Sensory Methodology

Seven or 8 trained panelists evaluated the odor and flavor characteristics of the canola oil samples subjected to storage (accelerated and practical) and heating (deep fat and shallow pan). Panelists evaluated the odor and flavor intensity of each oil sample and the strength of individual odor and flavor notes. Samples from the accelerated storage studies were evaluated first, followed by those stored for 5 months in PVC bottles. The evaluation of samples from the heating experiments was followed by samples stored for 10 months in PVC bottles.

Panel Selection and Training

Panelists were screened by a procedure described by Cross et al. (1978). Eighteen students and staff in the Department of Foods and Nutrition, University of Alberta, participated in the screening process which consisted of a series of 12 triangle tests. Samples represented a range of different oil types, flavored oils (buttery, grassy, lemony, fishy), and oxidized oils. Fourteen panelists were selected for training on the basis of their ability to correctly identify the odd sample greater than 60% of the time, their interest and availability.

Training sessions were held 3 to 4 times per week for 7 weeks. The first session introduced panelists to sensory evaluation and acquainted them with the evaluation procedure. Odor and flavor intensity of the oil samples were evaluated using a ten point intensity scale (1=extreme to 10=bland), which is the official method of the AOCS (Warner, 1985).

For the next 5 training sessions panelists evaluated odor and flavor intensity and described the odor and flavor notes present in the oil samples. A range of oxidized oil samples, as well as samples with odor and flavor characteristics of oxidized oils, such as grassy and fishy, was evaluated. After each session, results were recorded by the panel leader and discussed with the panelists. This discussion developed consistency among the panelists in evaluating oil intensity and acquainted panelists with the notes in the samples.

After becoming familiar with the concept of oil odor and flavor notes, panelists evaluated the strength of the notes in the oils as either weak, moderate or strong (Warner, 1985). A list of odor and flavor notes, compiled from the literature and the panel, was given to each panelist to assist in note identification. This list is presented in Appendix 1. Several sessions were held in which a series of oxidized oil samples were evaluated. Round table discussions were held to ensure that panelists used the same descriptors for specific notes.

After 12 training sessions, the final scorecard for the evaluation of stored canola oils was introduced (Appendix 2). Although the most frequently used notes for oxidized oil samples were listed on the scorecard, space was provided for additional notes. Panelists evaluated the strength of the notes on a 6 point scale (0=none to 5=very strong), as panelists frequently used a range of 6 different descriptors to describe the note strength.

Throughout training panelists were given a fresh canola oil sample as a reference. The reference was considered bland and equivalent to a 10 on the 10 point intensity scale. During the first 3 weeks of training panelists evaluated from 2 to 4 oil samples. During the fourth week this was increased to 5 samples.

During training panelists developed a procedure for the evaluation of oil samples. The procedure used is given in Appendix 3. The odor of all samples was evaluated first by shaking the sample vial, bringing it to the nose, removing the cap and taking 3-4 short sniffs. A recovery period of 30 sec was required between samples. The evaluation of the flavor of each sample was proceeded by clearing the palate with 1% lemon water (55°C), unsalted soda crackers and plain water (55°C). The flavor of all samples was evaluated by taking 3 ml of oil into the mouth (approximately 1/2 of the amount in the vial) and holding it in the mouth for 15 sec, exhaling through the nose several times. Panelists were instructed not to swallow oil samples. After expectorating the oil sample, panelists wiped their lips with a napkin to remove residual oil, before clearing the palate. Again a 30 sec recovery period was utilized. The odor and flavor of the oil samples were evaluated independently of each other.

After the fourth week of training, panel performance was evaluated using the procedure described by Cross et al. (1978). The evaluation consisted of 4 replications of 6 treatments which were representative of those anticipated in the actual study. Odor and flavor intensity data were analysed by a one-way analysis of variance. Individual F-values for each characteristic were combined and used as an indication of a panelist's performance. A high F-value indicated that a panelist was consistent in making repeated evaluations and was able to discriminate between the samples. On the basis of F-values, 2 panelists were dropped from the panel. Individual F-values and panelist means were also examined. One panelist had a very high F-value for flavor and a very low F-value for odor as compared to the other panelists. As well, all sample means for flavor for this panelist were much higher than the remainder of the panel, therefore this person was dropped from the panel. A fourth panelist was dropped due to illness.

During the sixth week of training the remaining ten panelists evaluated samples similar to those anticipated in the study. The number of samples evaluated per session was increased from 5 to 7 and 2 reference samples were given. Panelists were instructed to rate the first reference sample, then to evaluate the next 3 or 4 samples after which they were to assess the second reference sample. Timing for the evaluation of the second reference sample depended upon the strength of the first 3 samples.

A second panel evaluation was conducted as described earlier. The evaluation consisted of 4 replications of 7 treatments typical of those anticipated in the actual study. Odor and flavor intensity scores and note strength data were analysed as described by Cross et al. (1978). A total of 8 panelists were selected to participate in the study.

Prior to the evaluation of heated samples, 2 additional weeks of training were provided to solicit from the panel descriptors of the odor and flavor notes for heated canola oils. Oil samples similar to those to be evaluated in the actual study were employed. The scorecard for the evaluation of heated oil samples in shown in Appendix 4.

Before evaluating the samples stored for 10 months, 5 training sessions were held to once again aquaint panelists with the characteristics of stored oils as well as the scorecard for stored samples.

Sample Presentation

Panel sessions were held either daily or twice daily in an atmospherically controlled sensory panel room equipped with individual booths and red lights. Each panelist received a total of 7 samples per session to evaluate, 6 study samples and a hidden reference, as well as 2 reference samples. The order of sample presentation was randomized for each panelist. Each panelist evaluated oil samples from each treatment once per replicate for a total of 3 times per treatment. The oil samples (6 mls) were served warm in 20 ml glass vials with screw cap lids. Fifteen min prior to evaluation samples were warmed to 55°C, as per AOCS standards (Warner, 1985), in Corningware™ double boiler systems on Salton™ hotrays assembled in each booth. Panelists evaluated the odor of all samples and then the flavor. The instructions for evaluation appear in Appendix 3.

Studies in the literature (Mounts et al., 1978; Mounts et al., 1981; Ahmad et al., 1983) and recommendations from industry (Hoffman-LaRoche, 1985) did not indicate that ethanol would be detected by trained panelists. However, following 2 panel sessions, it became evident that the trained panel was able to detect the minute quantities of ethanol present in samples treated with AP. As a result, it was necessary to correct panel scores for the presence of ethanol. To do this, ethanol was added to reference oil in amounts identical to that used in the study (4 and 6 g ethanol/1000 g oil). Ethanol-oil samples were prepared following the same procedure used for antioxidant incorporation. Panelists evaluated the ethanol-oil samples 3 times. Mean intensity scores and odor and flavor intensity values for each panelist were used as individual correction factors. A correction factor was applied to the following samples:

Schaal Oven Storage - 0, 4 days
Fluorescent Light Storage - 0, 8, 16, 24 hours
Practical Storage - 0, 5, 10 months.

When two sessions were held on the same day, panelists were requested to leave 2 hours between sessions. Panelists were asked to refrain from eating, drinking or smoking for at least 1 hr prior to evaluation. As a motivational tool, small treats were given to the panelists at each session. At the end of the study panelists also received a small honorarium.

Odor and Flavor Notes, Data Handling

Odor and flavor intensity values (OIV and FIV, respectively) for all oil notes for each treatment by time combination were calculated as means across replicates. For OIV or FIV to be considered important to the evaluation of an oil sample, 25% of the panel had to report its presence (Mounts, 1979).

4. RESULTS AND DISCUSSION

Throughout the discussion T1 refers to the untreated canola oil control; T2, to canola oil treated with BHA/BHT + CA; T3, to canola oil treated with 100 ppm AP; T4, to canola oil treated with 200 ppm AP; T5, to canola oil treated with 200 ppm AP + CA; and T6, to the hidden control used for sensory analyses. The exact composition of each treatment can be found in Table 3, page 36.

The fresh canola oil used for all experiments was of good initial quality with IV between 119 and 117 and reasonably low PV (Table 4). The Canadian Processed Products Regulations (Canada Agricultural Products Standards Act, 1955) for canola oil require that fresh, refined, bleached and deodorized canola oil have an IV (Wijs) of not less than 110 and not more than 126, and a PV of less than 2.0 meq/kg. The canola oil standard (Section 43, Schedule II, Processed Product Regulations, Canada Agricultural Products Standards Act, 1955) also requires that canola oil contain less than 2% erucic acid (C22:1). The fresh canola oil used in all experiments had a C22:1 content of less than 1%. The linolenic acid (C18:3) content of the canola oil was between 10% and 11%. The C18:3 content of canola oil can range from 7% to 11% (Vaisey-Genser and Eskin, 1982). The low autoxidative and flavor stability of canola oil is due to the presence of polyunsaturated fatty acids, mainly C18:3.

Table 4. Chemical properties of canola oil upon receipt.

	Lot		
Parameter	1	2	3
Iodine Value (IV)	119.05	116.92	119.11
Peroxide Value (meq/kg)	0.21	0.31	0.26
Fatty Acid Composition (%)			
16:0	3.61	3.58	3.64
16:1	0.21	0.21	0.23
18:0	1.58	1.57	1.57
18:1	59.24	59.63	58.84
18:2	20.10	20.00	20.28
18:3	10.46	10.59	10.69
20:0	0.57	0.56	0.52
20:1	1.72	1.62	1.72
22:0	0.33	0.31	0.28
22:1	0.73	0.65	0.96

Accelerated Storage

Schaal Oven Test

Means and standard errors for chemical analyses of oils subjected to accelerated storage, at 65°C for up to 16 days, are presented in Table 5. Data for PV at 0 days storage indicate that all initial oil treatments were of good quality, with PV below 1 meq/kg. During storage for up to 8 days the PV for both T1 and T2 increased dramatically but T2 was significantly lower than T1. At this same time, the PV for the AP treated oils increased only slightly and the PV for T3, T4 and T5 were lower ($P<0.001$) than those of T1 and T2. After 12 days, the PV for T1 and T2 were similar and significantly higher than that of T3, which in turn was significantly higher than those for T4 and T5 (oils with 200 ppm AP). Although the PV for oils with 200 ppm AP increased markedly at 16 days, T4 and T5 still had PV that were lower ($P<0.001$) than those for T1, T2 and T3.

After 4 days of storage, the PV for the untreated and BHA/BHT treated canola oils increased from below 0.33 meq/kg (fresh oil) to 7.9 and 6.2 meq/kg, respectively. These values exceed that cited in the Canadian canola oil standards (Section 43, Schedule II, Processed Product Regulations, Canada Agricultural Products Standards Act, 1955) which require a PV below 2.0 meq/kg for high quality canola oil. Levels of peroxides similar to those obtained in the present study, were reported by Vaisey-Genser and Ylimaki (1985) and Hawrysh and Shand (1986) for untreated and BHA/BHT treated canola oils exposed to 4 days of oven storage. Following 8 days of storage, the oils containing

Table 5. Means[1] and standard errors for chemical analyses of canola oil, with and without antioxidant, following accelerated storage at 65°C.

Test	Storage Time (days)	Canola Oil Treatment Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[2]
Peroxide Value (meq/kg)	0	0.33	0.28	0.28	0.22	0.21	0.02
	4	7.93^{a}	6.23^{b}	0.88^{c}	0.89^{c}	0.72^{c}	0.30***
	8	20.01^{a}	17.99^{b}	1.75^{c}	1.28^{c}	1.14^{c}	0.39***
	12	29.25^{a}	28.12^{a}	17.11^{b}	2.41^{c}	3.62^{c}	0.44***
	16	37.72^{a}	36.66^{a}	28.41^{b}	18.36^{c}	17.77^{c}	0.98***
TBA1 (452 nm)	0	5.81^{b}	6.00^{b}	6.94^{a}	7.09^{a}	7.14^{a}	0.23**
	4	12.43^{a}	11.80^{a}	7.50^{b}	8.14^{b}	7.90^{b}	0.83**
	8	18.37^{a}	17.38^{a}	8.49^{b}	8.36^{b}	8.23^{b}	0.89***
	12	18.14^{a}	17.69^{a}	14.97^{a}	8.55^{b}	9.02^{b}	1.23**
	16	19.78^{a}	20.01^{a}	18.23^{a}	16.19^{b}	15.81^{b}	0.44***
TBA2 (532 nm)	0	2.34	2.29	2.22	2.16	2.32	0.07
	4	15.77^{a}	11.72^{b}	2.99^{c}	2.76^{c}	2.60^{c}	0.69***
	8	21.71^{a}	19.04^{b}	4.22^{c}	3.24^{c}	3.19^{c}	0.78***
	12	19.28^{a}	17.61^{a}	17.29^{a}	4.64^{b}	6.61^{b}	1.08***
	16	21.99^{a}	20.26^{abc}	21.29^{ab}	19.40^{bc}	18.58^{c}	0.49**
Conjugated Dienes (234 nm)	0	4.04	4.08	4.09	4.06	4.05	0.03
	4	4.70^{a}	4.58^{b}	4.19^{c}	4.16^{c}	4.13^{c}	0.03***
	8	5.80^{a}	5.67^{a}	4.21^{b}	4.18^{b}	4.17^{b}	0.05***
	12	6.81^{a}	6.65^{b}	5.52^{c}	4.22^{e}	4.42^{d}	0.04***
	16	7.78^{a}	7.72^{a}	6.78^{b}	5.84^{c}	5.76^{c}	0.08***
Conjugated Trienes (268 nm)	0	0.89	0.92	0.91	0.89	0.90	0.01
	4	0.96	0.94	0.93	0.92	0.92	0.01
	8	1.02	0.97	0.92	0.90	0.90	0.03
	12	1.06^{a}	1.05^{a}	0.96^{b}	0.91^{d}	0.93^{c}	0.01***
	16	1.14^{a}	1.14^{a}	1.02^{b}	0.96^{c}	0.96^{c}	0.01***

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[1] Means are averages of 6 determinations (2 per each of 3 replicates).

[2] Standard error of the mean.

[abcde] Means within the same row sharing a common letter are not significantly different at P<0.05.

[**,***] Significant differences among canola oil treatments at P<0.01 and P<0.001, respectively.

either 100 or 200 ppm AP, had PV below 2 meq/kg, which is typical of good quality oils. Oils treated with 200 ppm AP were still of relatively good quality following 12 days of storage with PV slightly above 2 meq/kg.

In this experiment, TBA numbers, measured at both 452 nm (TBA1) and 532 nm (TBA2), CD and CT were determined as measures of secondary oxidation products. At 0 days, the TBA1 numbers for the AP treated oils (T3, T4 and T5) were significantly higher than those for T1 and T2, which were similar. Perhaps AP addition to canola oils increased the amount of saturated and monounsaturated aldehydes present. Since studies comparing the TBA1 numbers of AP, BHA/BHT and untreated canola oils are lacking, the reason for this result is not readily apparent. After 4 days, differences among the oil treatments were as expected. At 4 and 8 days, TBA1 numbers for T1 and T2 were similar and significantly higher than those for the AP treated oils. At 12 days, the TBA1 numbers for T1, T2 and T3 were similar and significantly greater than those for T4 and T5. The TBA1 numbers for T4 and T5 increased at 16 days but they were significantly lower than those for T1, T2 and T3.

During Schaal oven tests, the TBA1 numbers for untreated and BHA/BHT treated canola oils increased rapidly up to 8 days of storage, after which the rate of increase slowed markedly. This finding supports the results of Hawrysh (1987) who noted similar trends for comparable treatments during Schaal oven tests. Reports on the changes in TBA1 numbers of AP treated canola oils during Schaal oven tests are lacking.

The TBA2 numbers at 0 days, indicate that all canola oil treatments contained similar amounts of diunsaturated aldehydes. At 4 and 8 days, the TBA2 values for the AP treated oils were lower ($P<0.001$) than that for T2, which was lower than that for T1. After 12 days, the TBA2 number for T3 (oil with 100 ppm AP) increased markedly and was similar to that for T1 and T2. The TBA2 numbers for oils treated with 200 ppm AP remained low at 12 days. At 16 days, TBA2 numbers for T4 and T5 increased and only differed significantly from T1.

The changes in TBA2 numbers of T1 and T2 during storage followed a pattern similar to that for TBA1 numbers. The TBA2 numbers for untreated and BHA/BHT treated canola oils increased rapidly up to 8 days of storage and then leveled off during subsequent storage. Similar findings were noted by Vaisey-Genser and Ylimaki (1985) and Hawrysh (1987). Literature on the effects of AP on diunsaturated aldehydes development (as measured by TBA2) in stored oils is unavailable.

In the present study, both TBA1 and TBA2 numbers were sensitive to changes in the oxidative state of the oils exposed to Schaal oven storage. Erdelyi (1983) suggested that TBA1 values were more sensitive than TBA2 numbers for measuring oxidative rancidity. However, Patton (1974) has criticized the use of TBA1 numbers, as aldehydes other than those produced by lipid oxidation may react to yield an absorbance maximum at 450 nm (TBA1). Thiobarbituric acid values should be compared with other chemical and sensory evaluation results to establish their reliability (Patton, 1974).

Conjugated diene values for all treatments were similar at 0 days. At each storage time throughout the 16 days, CD values for T1 and T2 tended to be similar and significantly higher than the values for comparable oils treated with AP. At 12 days, the CD value for T3 increased and was significantly higher than that for T5, which was also higher ($P<0.001$) than that for T4. At 16 days, CD values for oils containing 200 ppm AP increased but remained significantly lower than that for canola oil with 100 ppm AP.

Since the CD content of an oil indicates the presence of primary oxidation products, trends similar to those seen for PV would be expected. Careful examination of the data for the AP treated oils, indicates that where large increases in PV occur, the CD values also increase. However, similarities between the increases in PV and CD for T1 and T2 are not readilly apparent. Augustin and Berry (1983a) noted that trends for PV and CD were not always similar. In studies of the Schaal oven stability of BHA treated palm olein, Augustin and Berry (1983a) found that CD values increased smoothly over a 10 week period, while PV increased, then decreased, and then increased again. A similar trend in PV for stored BHA treated palm olein was found by Fritsch et al. (1975). They (Fritsch et al., 1975; Augustin and Berry, 1983a) suggested that the decrease in PV was a result of BHA destroying peroxides rather than retarding oxidation. The analyses of CD would not be subject to such fluctuations. Reports of CD values for stored canola oils, with or without antioxidants, are lacking.

Initial CT values for all treatments were similar. During storage of up to 8 days, CT values for T1 and T2 increased gradually, while those for T3-T5 remained relatively stable. At 12 and 16 days, CT values for T1 and T2 were similar and significantly higher than those for the AP treated oils. After 12 days, the CT value for the T4 was significantly lower than that for T5, which was lower ($P<0.001$) than that for T3. At 16 days, CT values for T4 and T5 were similar and significantly lower than that for T3.

The CT content of an oil denotes the presence of secondary oxidation products (IUPAC, 1978). In the present study, increases in CT during storage were relatively small. Augustin and Berry (1983a) also obtained only small increases in the CT values of stored palm olein. Reports for CT values of stored canola oil are unavailable.

Data for the Schaal oven test indicate that the addition of 200 ppm AP to canola oil retarded autoxidative degradation during storage at 65°C. Results from chemical analyses show a rapid deterioration in the quality of the untreated control and the BHA/BHT treated canola oils. Canola oils treated with either 100 or 200 ppm AP remained stable up to 8 days of storage. After 8 days, the quality of the 100 ppm AP treated oils deteriorated rapidly, as indicated by marked increases in PV, TBA numbers and CD values. Increases in CT values were apparent, but were not as marked. This rapid degradation of oil quality indicates the end of the induction period. Figure 4 clearly illustrates the induction period for canola oil treatments on the basis of PV. Both canola oils treated with 200 ppm AP (T4 and T5) remained stable for 12 days,

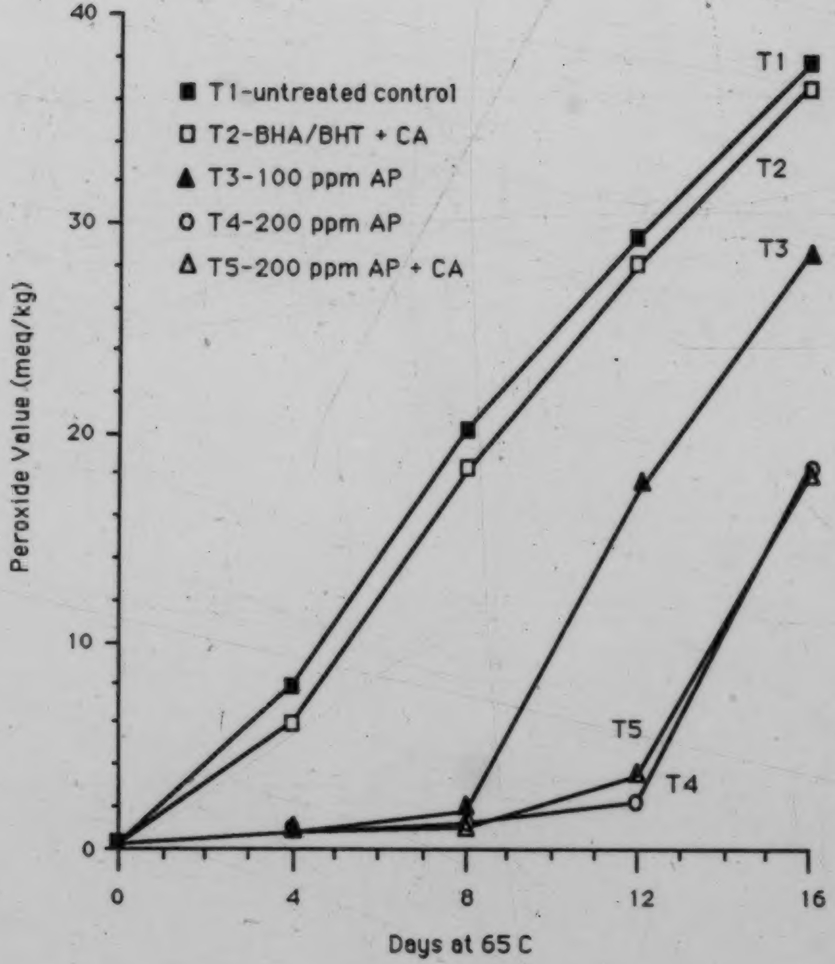

Figure 4. The effect of antioxidants on the PV of canola oil stored at 65°C.

following which there was a rapid deterioration in quality. Moreover, the quality of the oils treated with 200 ppm AP was significantly better than that of the other treatments.

Sensory evaluation data for canola oils stored at 65°C for up to 16 days are presented in Table 6. At 0 days, no significant differences among either odor or flavor intensity scores were found, indicating that initial oil treatments were of similar sensory quality.

At 4 days of storage, the odor intensity score for T3 (oil with 100 ppm AP) was significantly lower than that of T6 (the hidden control), while those for other treatments were similar to T6. In contrast, Hawrysh (1987) found that after 4 days of storage at 65°C, odor scores for untreated canola oil and canola oil treated with BHA/BHT, dropped to 6.8 and 7.2, respectively, and were significantly lower than a hidden control. A comparable drop in the odor scores of similar oil treatments was not seen in the current study. This may be a result of contrast effect, where the quality of one sample affects the score given to the next sample (Larmond, 1978). In this study, AP was incorporated into canola oil using ethanol as a carrier. The presence of ethanol in T3-T5 may have caused the odor intensity of T1 and T2 to be rated higher than normally expected, as these treatments did not contain ethanol. Usually contrast effect is equalized by randomization of the order of sample presentation for each panelist. However, in the current study, it would be difficult to equalize contrast effect as the number of samples which may have caused a contrast effect exceeded those which would not.

Table 6. Means and standard errors for odor and flavor intensity scores for canola oil, with and without antioxidant, following accelerated storage at 65°C.

Characteristic	Storage Time (days)	Canola Oil Treatment Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)	SEM[1]
Overall Odor	0	9.8	9.7	9.6	9.5	9.4	9.8	0.24
Intensity[2]	4	9.3^{ab}	9.1^{ab}	8.7^{b}	9.0^{ab}	9.2^{ab}	9.8^{a}	0.17*
	8	5.1^{c}	5.6^{c}	8.7^{ab}	9.0^{ab}	8.1^{b}	9.5^{a}	0.24***
	12	4.5^{e}	4.7^{e}	6.9^{d}	9.0^{b}	8.2^{c}	9.8^{a}	0.20***
	16	3.5^{d}	4.6^{c}	5.0^{c}	6.9^{b}	6.8^{b}	9.8^{a}	0.33***
Overall Flavor	0	9.8	9.7	9.5	9.4	9.4	9.8	0.10
Intensity[2]	4	9.4^{ab}	8.9^{b}	8.5^{b}	8.5^{b}	8.4^{b}	9.8^{a}	0.21**
	8	4.2^{c}	4.9^{c}	8.0^{b}	8.1^{b}	7.5^{b}	9.5^{a}	0.27***
	12	3.8^{e}	4.7^{d}	6.3^{c}	7.6^{b}	6.8^{bc}	9.5^{a}	0.26***
	16	3.5^{d}	4.4^{cd}	5.5^{bc}	6.7^{b}	6.6^{b}	9.7^{a}	0.40***

[1] Standard error of the mean.

[2] Ten point scale, 10=maximum. Lower values indicate increasing odor and flavor intensity. Means are averages of 21 scores (7 panelists, 3 replications).

[abcde] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

[*,**,***] Significant differences among canola oil treatments at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

At 8 days, odor scores for T1 and T2 dropped and were lower ($P<0.001$) than those for T3-5; however, only T3 and T4 were similar to T6. At each time period after 12 days, all stored oils had odor scores that were lower ($P<0.001$) than the hidden control. At 12 days, odor scores for T4 and T5 (200 ppm AP) differed and both were significantly higher than that of T3 (100 ppm AP). At 16 days, the scores for T4 and T5 dropped, but were similar and higher ($P<0.001$) than odor scores for T2 and T3, which were similar and higher than that of T1.

After 4 days of storage, the flavor intensity score for T1 did not differ from T6, however, flavor scores for the antioxidant treated oils (T2-T5) were lower ($P<0.01$) than that of T6. Hawrysh and Shand (1986) reported that after 4 days of storage at 65°C, flavor scores for untreated canola oil and canola oil treated with BHA/BHT, dropped to 6.1 and 6.4, respectively, and both were significantly lower than that for a hidden control. In the present study, a comparable drop in flavor scores for T1 and T2 was not observed. This may be due to contrast effect, previously discussed.

At each time following 8 days, the flavor scores for all stored oils were lower ($P<0.001$) than those for the hidden control. At 8 days, the scores for T1 and T2 dropped dramatically and were much lower than those for T3-T5, which were similar. After 12 days, the flavor scores for the AP treated oils were higher than those for T1 and T2, with that for T4 being the highest. At 16 days, scores for AP treated oils were similar and significantly higher than that for T1, but the scores for T2 and T3 were similar.

Odor and flavor descriptions (notes) and note intensities were obtained to further characterize the sensory quality of the stored oils. Odor intensity values (OIV) for canola oils, stored at 65°C for up to 16 days, are presented in Appendix 5. Initially, all oil treatments were similar to the hidden control, as indicated by the absence of odor notes at 0 days of storage. After 8 days, panelists reported the presence of painty odor notes. Painty notes are indicative of oil deterioration during storage (Mounts et al., 1981). The effect of antioxidants on painty odor development in oil samples is shown in Figure 5. At 8 days, painty OIV for T1 and T2 increased markedly to levels representative of moderate and slight ratings, respectively, on a 6-point scale where 0=not present and 5=very strong. Throughout further storage, painty OIV in T1 and T2 increased only slightly. During storage up to 8 days, the presence of AP (100 or 200 ppm) inhibited painty odor development. However, at 12 days, painty OIV in T3 (100 ppm AP) increased to a level indicative of slight, while those for T4 and T5 (200 ppm AP) remained low. At 16 days, painty odors increased in T3 to moderate levels, and in T4 and T5, to levels repesentative of slight.

Flavor intensity values (FIV) for canola oils, stored at 65°C for up to 16 days, are given in Appendix 6. Initially, all oil treatments were similar to the hidden control. At each storage time, grassy FIV for oil treated with 200 ppm AP and CA (T5), were consistently higher than those obtained for other treatments. Panelists noted the presence of painty flavors following 8 days of storage. The effect of antioxidants on painty flavor development in canola oils is illustrated in Figure 6.

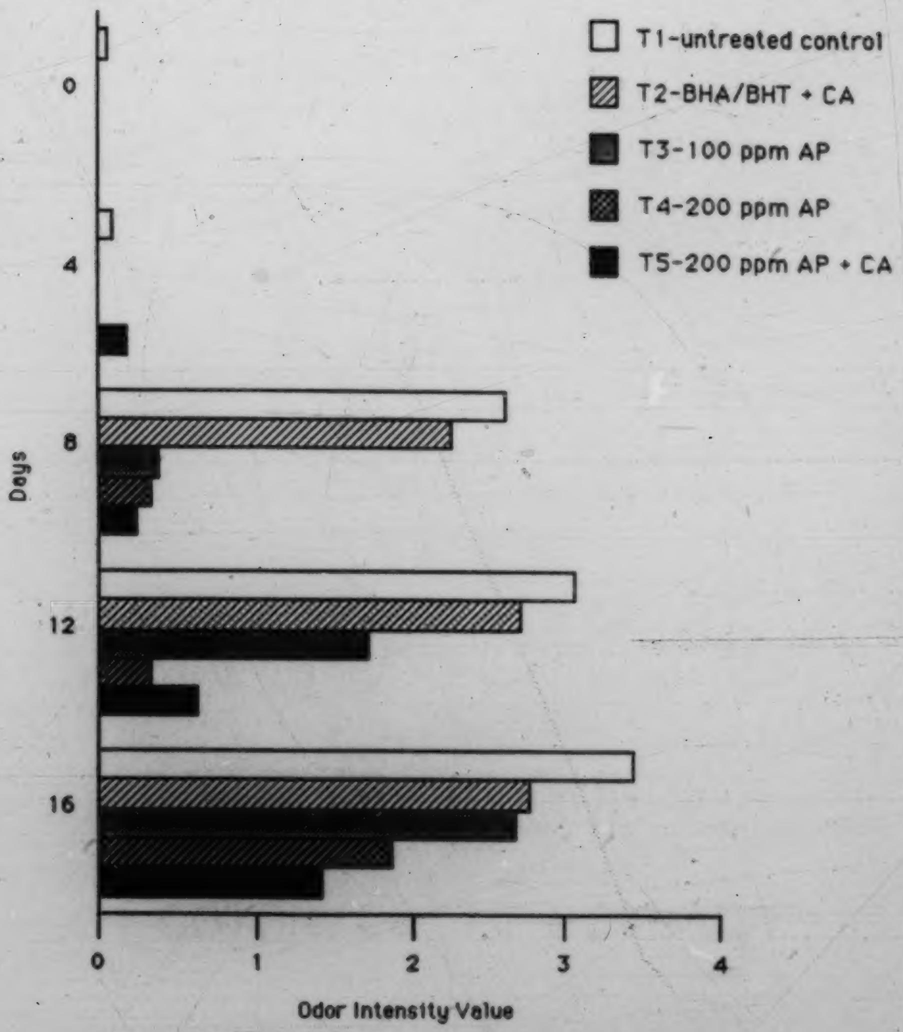

Figure 5. The effect of antioxidants on painty odor development in canola oil stored at 65°C.

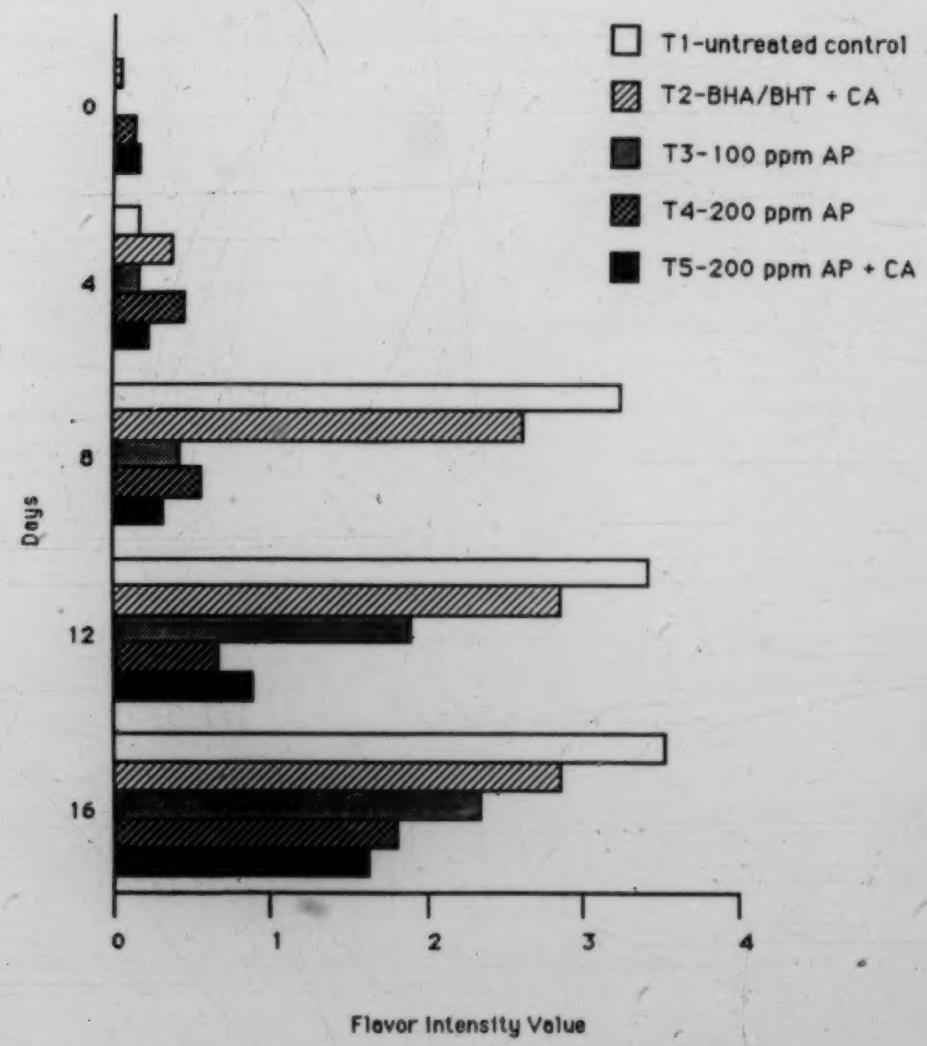

Figure 6. The effect of antioxidants on painty flavor development in canola oil stored at 65°C.

The pattern of painty flavor development in the oils was similar to that for painty odor development. Painty FIV increased markedly in T1 and T2 at 8 days, and in T3 at 12 days; however, only slight increases in FIV were obtained for these treatments during further storage. The presence of 200 ppm AP delayed the development of painty flavors during storage.

The odor and flavor notes obtained in the present study were indicative of the deterioration in oil quality that occurs during Schaal oven storage. Researchers (Cowan et al., 1970; Mounts et al., 1979; Mounts et al., 1981) studying the Schaal oven stability of soybean oil, reported that painty odors and flavors developed after 8 days. Painty odors and flavors in oils indicate that severe flavor deterioration has occurred (Mounts et al., 1981).

Sensory evaluation results show trends similar to those found for the chemical analyses following 4 days of storage. At 8 days, odor and flavor scores for the AP treated oils were no more than 2 points lower than that of the hidden control and contained low levels of painty notes. In contrast, odor and flavor scores for the untreated control and the BHA/BHT treated canola oil were approximately 4 or 5 points lower, respectively, than the hidden control. These oils (T1 and T2) contained relatively high amounts of painty notes at 8 days. Similar decreases in odor and flavor intensity scores for comparable treatments were noted by Hawrysh and Shand (1986). At 12 days, there was a decrease in the odor and flavor quality of the oil treated with 100 ppm AP. The odor scores of the oils treated with 200 ppm AP remained fairly stable up to 12 days. At 16 days, odor scores for oils treated with 200 ppm AP dropped but they were higher than those of the other treatments. During storage, the flavor scores of the oils containing 200 ppm AP tended to show a gradual decrease, but remained higher than those for the control and the BHA/BHT treated oils. These odor and flavor scores for 200 ppm AP treated oils (at 16 days) were indicative of a rating of slightly intense on a 10-point scale, where 10=bland and 1=extreme. However, odor and flavor scores for the untreated and BHA/BHT treated oils were representative of moderate to strong intensity. Information from trained panel evaluations of AP treated canola oils is lacking.

The results of sensory and chemical analyses show that 200 ppm AP retarded canola oil autoxidation during Schaal oven tests. Data indicate that the addition of 200 ppm AP to canola oil was more effective than 100 ppm AP in promoting oxidative stability. McConnell and Esselen (1947) and Pongracz (1973) also reported that the incorporation of increasing amounts of AP into vegetable oils resulted in increased protection from autoxidation.

The addition of CA to canola oil containing 200 ppm AP did not improve autoxidative stability compared to oils treated with AP alone. Chemical data for T4 and T5 were similar at each time during storage. Odor and flavor intensity scores for oils treated with both AP and CA (T5) tended to be slightly lower than that for T4 (200 ppm AP alone).

Chemical and sensory data for the Schaal oven test show that T2 (BHA/BHT and CA) was ineffective in extending canola oil oxidative stability. Few differences were found between data for the untreated control and the BHA/BHT treated canola oils. Generally, at 16 days, there were no differences between the chemical or sensory data of the control and the BHA/BHT treated canola oils. These findings support the research of Vaisey-Genser and Ylimaki (1985) and Hawrysh and Shand (1986) who also reported that BHA/BHT was ineffective in extending the Schaal oven stability of canola oil and that the stability of BHA/BHT treated canola oils was similar to that of the untreated control (Hawrysh and Shand, 1986). Others (Rhee, 1978; Mounts et al., 1978) have shown that the combination of BHA and BHT is ineffective in extending the storage stability of either soybean oil or a soybean-cottonseed oil blend.

Fluorescent Light Storage

Means and standard errors for chemical analyses of canola oils subjected to fluorescent light exposure are presented in Table 7. At 0 hr, data for PV indicate that all oil treatments were of good quality and contained low quantities of peroxides. At each storage time throughout the 24 hr period, PV for all treatments increased but the PV for AP treated oils were similar and significantly lower than those for the untreated control and oil treated with BHA/BHT. After 8 hr, the PV for all treatments were above 2 meq/kg, the PV cited in the canola oil standard (Section 43, Schedule II, Processed Product Regulations, Canada Agricultural Products Standards Act, 1955) for a high quality oil. Hawrysh (1987), studying the efficacy of antioxidants in canola oils, reported PV of 8.3 and 7.6 meq/kg for untreated and BHA/BHT treated oils, respectively, following 24 hr of exposure to fluorescent light (7532 lux). Peroxide values obtained in the present study for

Table 7. Means[1] and standard errors for chemical analyses of canola oil, with and without antioxidant, following exposure to fluorescent light (7532 lux).

Test	Storage Time (hr)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[2]
Peroxide Value (meq/kg)	0	0.43	0.38	0.34	0.33	0.32	0.02
	8	4.44^a	4.44^a	3.66^b	3.61^b	3.44^b	0.11***
	16	7.74^a	7.56^a	5.92^b	5.57^b	5.44^b	0.15***
	24	13.79^a	12.76^a	9.85^b	8.80^b	8.82^b	0.38***
TBA1 (452 nm)	0	4.93^b	4.76^b	6.03^a	5.78^a	5.77^a	0.21**
	8	8.89	8.15	8.43	7.97	8.02	0.24
	16	10.49^a	10.02^{ab}	9.44^{bc}	9.06^c	8.70^d	0.20**
	24	11.63^a	11.34^a	10.53^b	10.24^b	9.42^c	0.16***
TBA2 (532 nm)	0	2.06	2.00	2.00	2.06	1.90	0.05
	8	3.20^a	3.01^{ab}	2.84^b	2.78^b	2.70^b	0.08*
	16	5.04^a	4.83^a	3.54^b	3.23^{bc}	2.96^c	0.10***
	24	9.37^a	7.65^b	5.10^c	4.23^d	3.93^d	0.24***
Conjugated Dienes (234 nm)	0	4.10	4.16	4.10	4.15	4.09	0.03
	8	4.28	4.26	4.20	4.20	4.20	0.03
	16	4.44	4.43	4.35	4.28	4.28	0.05
	24	4.62^a	4.59^a	4.36^b	4.37^b	4.28^b	0.04**
Conjugated Trienes (268 nm)	0	0.90^b	0.92^a	0.90^b	0.91^{ab}	0.90^b	0.00*
	8	0.91	0.91	0.88	0.89	0.89	0.01
	16	0.90	0.90	0.89	0.88	0.88	0.01
	24	0.86	0.88	0.86	0.86	0.85	0.00

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[1] Means are averages of 6 determinations (2 per each of 3 replicates).

[2] Standard error of the mean.

[abcd] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

[*,**,***] Significant differences among canola oil treatments at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

similar treatments and times, were approximately 1.7 times higher than those found by Hawrysh (1987), although the initial PV for samples in both studies were similar. Literature on the effects of AP on peroxide formation in canola oil exposed to fluorescent light is lacking.

At 0 hr, TBA1 numbers for AP treated oils were significantly higher than those for the untreated control and oil treated with BHA/BHT. At 8 hr, no differences were found among treatments for TBA1 numbers. After 16 hr, the TBA1 numbers for T1 and T2 were similar and higher ($P<0.01$) than those for the 200 ppm AP treated oils, of which T5 was the lowest. At 24 hr, the TBA1 number for T5 was significantly lower than those of T3 and T4, which were the same and significantly lower than the TBA1 numbers for T1 and T2. As storage time was extended, the TBA1 numbers for all treatments increased. The greatest increase in the TBA1 numbers of T1 and T2 occurred during the first 8 hr. However, the TBA1 numbers for the AP treated oils increased gradually. The TBA1 values for T1 and T2 increased to 11.63 and 11.34, respectively, during the 24 hr of storage. Similar TBA1 numbers for comparable canola oil treatments were noted by Hawrysh (1987) during fluorescent light storage. Reports on the TBA1 numbers of AP treated canola oils are unavailable.

Initially, there were no significant differences in TBA2 numbers due to treatment. However, at 8 hr, the TBA2 numbers for all of the AP treated oils were similar and differed ($P<0.05$) from that for T1. After 16 hr, the TBA2 numbers for the AP treated oils were lower ($P<0.001$) than those for T1 and T2, with that for T5 being the lowest. At 24 hr, the TBA2 values for T4 and T5 were similar and lower ($P<0.001$) than that for T3. In addition, the TBA2 numbers for T1 and T2 were higher ($P<0.001$) than those for the AP treated oils, with that for T1 significantly higher than that for T2. The TBA2 data for all oil treatments increased gradually as storage time increased. During storage the TBA2 numbers for for T1 and T2 increased by a factor of 4.5 and 3.8, respectively. Hawrysh (1987), studying the TBA2 numbers of similar canola oil treatments during fluorescent light tests, reported increases by a factor of 6.0 for untreated canola oils and 8.5 for BHA/BHT treated canola oils. Information on diunsaturated aldehyde development (as measured by TBA2) in AP treated oils is lacking.

The determination of TBA1 and TBA2 numbers was relatively sensitive to changes in the photooxidative state of the oils exposed to fluorescent light. As previously discussed, TBA values should be compared to other chemical and sensory evaluation data to establish their reliability.

Conjugated diene values for all oil treatments exposed to fluorescent light, were similar at each storage time up to 16 hr. At 24 hr, CD values for the AP treated oils were significantly lower than those for T1 and T2, which were the same. The CD values for all treatments increased gradually as storage time was extended. Reports of CD formation in oils exposed to fluorescent light are unavailable.

At 0 hr, slight but significant differences in CT values of the oils were obtained. At 0 hr, the CT value for T2 was greater than those for T1, T3 and T5. At each storage time during further exposure to fluorescent light, no differences in the CT of the oil samples were found. Information regarding the development of CT in oils exposed to fluorescent light is needed.

On the basis of PV, Moser et al. (1965a) reported that the exposure of soybean oil to 1 hr of fluorescent light (7532 lux) is equal to 4 days of Schaal oven storage. However, in the present study, PV obtained for oils after 4 days of Schaal storage were similar to those found following 16 hr of fluorescent light exposure. More research is necessary before conclusions regarding possible similarities between fluorescent light exposure and oven storage can be made for canola oils.

Means and standard errors for sensory data for oils stored under fluorescent light appear in Table 8. At 0 hr, the odor scores for the exposed oils were similar to that of the hidden control. Following 8 hr, the odor scores for T4 and T5 were similar to that for T6, while those for T1, T2 and T3 were significantly lower than that of T6. Odor scores for all of the oil treatments exposed to 16 hr of fluorescent light were similar and significantly lower than that for the hidden control. After 24 hr, odor scores for both T4 and T5 were significantly lower than that for T6 but higher ($P<0.001$) than those for T1, T2 and T3, which were similar.

Initially, the flavor scores of the AP treated oils were significantly lower than that for the hidden control, however, differences were slight. This finding may be due to the presence of ethanol in T3-5. At each subsequent fluorescent light exposure time,

Table 8. Means and standard errors for odor and flavor intensity scores for canola oil, with and without antioxidant, following exposure to fluorescent light (7532 lux).

		Canola Oil Treatment						
Characteristic	Storage Time (hr)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)	SEM[1]
Overall Odor	0	9.7	9.8	9.6	9.5	9.4	9.8	0.20
Intensity[2]	8	7.3^b	7.3^b	7.8^b	8.8^{ab}	8.5^{ab}	9.7^a	0.34**
	16	5.9^b	6.7^b	6.9^b	7.1^b	7.0^b	10.0^a	0.38***
	24	5.7^c	5.7^c	6.4^c	7.1^b	7.3^b	9.7^a	0.22***
Overall Flavor	0	9.6^{abc}	9.8^{ab}	9.5^{bc}	9.4^c	9.4^c	9.8^a	0.08*
Intensity[2]	8	7.2^b	7.1^b	7.0^b	7.0^b	7.1^b	10.0^a	0.34***
	16	5.8^b	6.1^b	6.0^b	6.2^b	6.5^b	10.0^a	0.33***
	24	5.3^b	5.0^b	5.9^b	6.0^b	5.5^b	9.7^a	0.27***

[1] Standard error of the mean.

[2] Ten point scale, 10=maximum. Lower values indicate increasing odor and flavor intensity. Means are averages of 21 scores (7 panelists, 3 replications).

[abc] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

[*,**,***] Significant differences among canola oil treatments at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

flavor scores for all oil treatments were similar and significantly lower than that for the hidden control.

As the length of fluorescent light exposure increased, the odor and flavor intensity scores for all treatments dropped to levels representative of mild to slight intensity. Generally, the greatest decrease in oil odor and flavor scores occurred between 0 and 8 hr of exposure, after which the rate of decrease slowed. Similar trends were noted in trained panel data reported by Hawrysh (1987) for canola oils exposed to fluorescent light. Reports on the sensory quality of AP treated canola oils exposed to fluorescent light are lacking.

Odor intensity values for canola oils subjected to fluorescent light (7532 lux) for up to 24 hr, are presented in Appendix 7. At 8 hr, rancid odors were present in T1 and T2. The addition of AP to canola oil delayed rancid odor development up to 8 hr. Rancid odors were present in all samples exposed to fluorescent light for 16 hr. After 8 hr of exposure and longer, a variety of other odor notes, which included sour, acid, fruity, lemony and bitter, developed in T1, T2 and T3. Following 16 hr, similar odor notes were also detected in T4 and T5.

Flavor intensity values for canola oils subjected to fluorescent light appear in Appendix 8. Fishy flavors developed in T1, T2 and T4 following 24 hr of fluorescent light exposure. Grassy, painty and rancid flavors were noted in oils after 8 hr. Generally, the addition of either BHA/BHT or AP to canola oil did not delay the development of fishy, grassy, painty or rancid flavors.

Literature on the development of specific odor and flavor notes in antioxidant treated canola oils exposed to fluorescent light is lacking. Researchers (Moser et al., 1965a, 1965b; Warner et al., 1978) have reported the presence of a pronounced grassy flavor, as well as rancid and fruity notes in a number of oils exposed to fluorescent light. In the present study, grassy, painty and rancid FIV increased to levels representative of very slight.

Generally, the chemical data indicate that AP inhibited photooxidative degradation of canola oil during fluorescent light exposure. The incorporation of 200 ppm AP in canola oil resulted in lower PV, TBA1 and TBA2 numbers, and CD values following 24 hr of exposure to fluorescent light, than were found in either the untreated control or the BHA/BHT treated oils. Trained panel data indicate that 200 ppm AP improved the odor characteristics, but had only a slight and generally nonsignificant effect on the flavor characteristics of canola oil subjected to fluorescent light. In contrast, McConnell and Esselesen (1947) noted that 0.02% to 0.10% AP inhibited off flavor development in corn and cottonseed oils exposed to fluorescent light.

The addition of CA to canola oil treated with 200 ppm AP did not enhance the photooxidative stability of canola oil as indicated by PV, TBA2, CD, CT and trained panel evaluations. The addition of CA to AP treated canola oil inhibited the development of unsaturated and monounsaturated aldehydes (as measured by TBA1) during 24 hr of exposure to fluorescent light. Citric acid chelates metals which catalyze the formation of free radicals. Since photooxidation does not involve free radical formation (Carlsson et al., 1976), the addition of CA would not be expected to enhance oil stability under these conditions.

The incorporation of BHA/BHT into canola oils subjected to fluorescent light was ineffective in retarding photooxidation. At each storage period throughout the 24 hr of exposure, no differences were found between the BHA/BHT treated canola oil and the untreated control for PV, TBA1 and CD. The TBA2 number for the BHA/BHT treated oil was only lower than that of the untreated control at 24 hr. In an earlier study, Hawrysh (1987) found that the addition of BHA/BHT to canola oil was ineffective in retarding photooxidation. Mounts et al. (1978) reported that BHA/BHT did not improve the flavor stability of unhydrogenated soybean oil (8.3% linolenate) exposed to fluorescent light, but did improve the flavor stability of 2 hydrogenated soybean oils (3.3% and 0.4% linolenate).

Correlations for Accelerated Storage

Pearson correlation coefficients for the sensory and chemical data from both accelerated storage tests are presented in Table 9. All coefficients show highly significant relationships between sensory and chemical data. Leporiere (1976) suggested that correlation coefficients were poor if $r \leq 0.25$; fair if r is between 0.26 and 0.50; good if r is between 0.51 and 0.75, and excellent if $r \geq 0.76$, irrespective of sign. In the present study, low numbers indicate increasing strength for odor and flavor intensity scores. For chemical data, high numbers denote marked degradation. Thus, the negative correlations are as expected.

Table 9. Pearson correlation coefficients (r) between sensory evaluation data and chemical data for accelerated storage tests.

Test	Schaal Oven Storage (N=75)		Fluorescent Light Storage (N=60)	
	Odor Scores	Flavor Scores	Odor Scores	Flavor Scores
Peroxide Values	-0.94***	-0.88***	-0.87***	-0.86***
TBA1 (452 nm)	-0.78***	-0.76***	-0.91***	-0.91***
TBA2 (532 nm)	-0.82***	-0.78***	-0.78***	-0.71***
CD (234 nm)	-0.94***	-0.88***	-0.74***	-0.73***
CT (268 nm)	-0.84***	-0.80***	0.41***	0.46***

*** Significant at $P<0.001$.

All correlation coefficients determined for data from Schaal oven tests were "excellent". Correlations for results from the fluorescent light test were generally excellent, with the exception of those for CD and sensory data, and that between TBA2 and flavor scores, which were good. Correlations for CT and sensory data from the fluorescent light test were fair.

Recently, in a related evaluation of canola oil stability, Hawrysh (1987), reported similar correlation coefficients between PV and odor and flavor scores for Schaal oven storage. Researchers (Dutton et al., 1948; Hawrysh, 1987) have noted that correlations between sensory data and the logarithms of PV yield slightly higher r values than those determined for sensory data and PV. However, in the present study, correlations between odor and flavor intensity scores with the logarithm of the PV (data not shown) did not improve r values.

For the Schaal oven test, correlation coefficients for TBA1 numbers were similar to those for TBA2. Hawrysh (1987) also noted similar correlation coefficients for TBA1 and TBA2 numbers with odor and flavor intensity scores for Schaal oven storage. Jacobson et al. (1964) found that the reciprocal of the absorbance at 532 nm (TBA2) showed a well defined relationship with flavor scores, however, the reciprocal of the absorbance at 432 nm (TBA1) did not. Jacobson et al. (1964) suggested that dienals (as measured by TBA2) were a major factor in the development of off flavor in soybean oil rather than saturated and mono-unsaturated aldehydes (as measured by TBA1). According to Jacobsons' (1964) proposal, one could expect correlations between TBA2 numbers and sensory scores, to be higher than those for TBA1 numbers. However, in the present study and that of Hawrysh (1987), coefficients obtained for TBA1 and TBA2 were similar.

Correlation coefficients for TBA1 obtained from the fluorescent light test (Table 9), were higher than those for TBA2. Hawrysh (1987) noted slightly lower coefficients between TBA values and sensory data, than those obtained in the current study. However, Hawrysh (1987) also found that coefficients for TBA1 numbers were slightly higher than those for TBA2. Studies reporting correlations for panelist assessments of odor and flavor intensity with CD and CT are lacking.

Practical Storage

Means and standard errors for chemical analyses of canola oil stored in PVC bottles for up to 1C months, are presented in Table 10. At 0 time, PV for T4 and T5 were signifcantly lower than those for other treatments. However, all PV at 0 time were below 1 meq/kg. Fresh oil should have a PV below 1 meq/kg (Rossell, 1986). During each storage time, PV for all treatments increased. Although the PV for T5 were lower than values for other samples, no significant differences due to antioxidant treatment were found at 5 and 10 months.

Initially, the TBA1 numbers for the AP treated oils were higher ($P<0.001$) than those for T1 and T2. Similar results for TBA1 at 0 time were obtained for both accelerated storage tests. No significant differences were found in TBA1 numbers at subsequent storage periods.

Table 10. Means[1] and standard errors for chemical analyses of canola oil, with and without antioxidant, after practical storage in PVC bottles and exposure to fluorescent light (1400 lux) 12 hr/day.

		Canola Oil Treatment					
Test	Storage Time (months)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[2]
Peroxide	0	0.38^{a}	0.38^{a}	0.33^{a}	0.21^{b}	0.23^{b}	0.03**
Value	5	9.04	9.83	13.38	9.06	8.95	3.70
(meq/kg)	10	26.68	49.47	29.00	26.65	18.25	9.89
TBA1	0	6.33^{b}	6.20^{b}	7.43^{a}	8.15^{a}	7.81^{a}	0.28**
(452 nm)	5	17.60	18.84	22.16	18.45	18.84	3.16
	10	48.56	70.85	53.80	49.46	39.18	9.33
TBA2	0	2.94	2.68	2.67	2.71	2.69	0.14
(532 nm)	5	14.94	17.24	17.98	10.08	8.91	6.46
	10	64.82	101.62	74.75	66.08	44.29	19.23
Conjugated	0	4.07	4.08	4.06	4.08	4.09	0.22
Dienes	5	4.40	4.55	4.56	4.24	4.22	0.29
(234 nm)	10	6.35	8.62	6.42	5.97	5.32	0.87
Conjugated	0	0.78	0.79	0.78	0.78	0.78	0.00
Trienes	5	0.76	0.77	0.76	0.75	0.76	0.00
(268 nm)	10	0.79^{ab}	0.88^{a}	0.76^{ab}	0.73^{b}	0.71^{b}	0.03*

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[1] Means are averages of 6 determinations (2 per each of 3 replicates).

[2] Standard error of the mean.

[ab] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

*, ** Significant differences among canola oil treatments at $P<0.05$ and $P<0.01$, respectively.

For each storage time throughout the 10 months, no significant differences among oil treatments were found for either TBA2 or CD. Conjugated triene values for the oil treatments were similar at 0 and 5 months. At 10 months, CT values for T4 and T5 were similar and lower ($P<0.05$) than that for T2.

Means and standard errors for sensory analyses of samples subjected to practical storage are given in Table 11. At 0 time, odor and flavor scores for all oils indicated that they were of similar good quality. However, at 5 and 10 months, odor scores for stored oils were similar and significantly lower than that for the hidden control. At 5 months, flavor scores for all stored oils were significantly lower than that for the hidden control; and those for T3 and T5 were significantly lower than that for T2. At 10 months, the flavor scores for all stored samples were lower ($P<0.001$) than that for the hidden control, however, that for T2 was significantly lower than those for the other stored oils, which were similar.

The large standard errors obtained for the chemical analyses (Table 10) show that large variations were present in the samples. Data for PV, and odor and flavor intensity scores for each replicate (Table 12) illustrate the extent of variability among replicates for the samples. Similar patterns were found for other chemical data across replicates. Data for PV at 10 months are especially interesting. The low PV (4.76 meq/kg) for T1 is unexpected and no reason for this finding is readily apparent. Odor and flavor intensity scores for samples with low PV (T1, Rep 1; T4, Rep 1; T5, Rep 2) tended to be higher than those obtained for

Table 11. Means and standard errors for odor and flavor intensity scores for canola oil, with and without antioxidant, after practical storage in PVC bottles and exposure to fluorescent light (1400 lux) 12 hr/day.

		Canola Oil Treatment						
Characteristic	Storage Time (months)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)	SEM[1]
Overall Odor	0	9.8	9.7	9.6	9.5	9.4	9.8	0.24
Intensity[2]	5	7.4^{b}	6.7^{b}	6.5^{b}	7.7^{b}	7.0^{b}	9.8^{a}	0.58*
	10	7.4^{b}	6.5^{b}	7.1^{b}	7.8^{b}	7.7^{b}	9.6^{a}	0.37**
Overall Flavor	0	9.8	9.7	9.5	9.4	9.4	9.8	0.10
Intensity[2]	5	6.4^{bc}	6.8^{b}	5.2^{c}	5.7^{bc}	5.3^{c}	9.8^{a}	0.33***
	10	6.8^{b}	5.0^{c}	7.0^{b}	6.8^{b}	6.6^{b}	9.8^{a}	0.40***

[1] Standard error of the mean.

[2] Ten point scale, 10=maximum. Lower values indicate increasing odor and flavor intensity. Means are averages of 21 scores (7 panelists, 3 replications).

[abc] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

[*,**,***] Significant differences among canola oil treatments at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

Table 12. Odor and flavor intensity scores and PV by replicate for canola oil, with and without antioxidant, after practical storage in PVC bottles and exposure to fluorescent light (1400 lux) 12 hr/day.

Test	Storage Time (months)	Rep	Canola Oil Treatment Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)
Odor Intensity[1]	5	1	8.1	7.7	6.4	7.7	8.0
		2	8.3	6.7	6.0	8.3	8.0
		3	5.7	5.7	7.1	7.1	7.1
Flavor Intensity[1]	5	1	7.6	7.4	5.3	5.7	5.7
		2	6.6	6.3	4.9	6.0	5.0
		3	5.0	6.6	5.4	5.3	5.3
PV[2] (meq/kg)	5	1	4.16	5.14	15.28	10.58	9.60
		2	4.22	20.37	13.18	5.34	9.45
		3	18.74	4.00	11.70	11.27	7.80
Odor Intensity[1]	10	1	8.7	6.3	6.4	8.3	7.7
		2	6.6	6.7	7.4	7.4	8.1
		3	6.6	6.4	7.4	7.6	7.1
Flavor Intensity[1]	10	1	8.1	5.6	6.6	7.0	6.0
		2	5.7	4.7	6.6	6.4	7.1
		3	6.4	4.6	7.7	6.9	6.7
PV[2] (meq/kg)	10	1	4.76	48.18	26.84	4.20	37.14
		2	48.61	49.18	17.90	38.58	4.16
		3	26.68	51.05	42.26	37.18	13.46

[1] Values are means of 7 scores (1 per each of 7 panelists)

[2] Values are means of duplicate determinations.

identical treatments from the remaining 2 replicates.

Other researchers (Evans et al., 1973; Hung and Slinger, 1981; Hawrysh, 1987) have also noted peculiar data for oils stored for long periods of time. Evans et al. (1973) reported erratic PV during long term storage at 38°C of soybean oil, bottled with N_2 in the headspace. The erratic values were attributed to poor seals on the bottles, which possibly resulted in air leakage into the headspace (Evans et al., 1973). In the present study, particular care was taken to ensure that the cap on each bottle of oil was tightly closed by hand. Thus, no reasons for the erratic values in the current study are readily apparent. Perhaps poor seals on some PVC bottles may account for the variable results. During autoxidation and photooxidation, available O_2 catalyzes oil degradation. If O_2 in the headspace is depleted, oil autoxidation and photooxidation may be inhibited. However, a poor seal on a bottle would permit the exchange of headspace gases with the atmosphere and O_2 would be available for oil oxidation.

Odor intensity values for oils subjected to practical storage are presented in Appendix 9. Grassy odors were found in T2 after 10 months of storage, but were not prominent in other treatments. At both 5 and 10 months, painty odors were detected in T2 and T3 . Rancid odors were generally noted in all samples stored for 5 and 10 months.

Flavor intensity values for oils (Appendix 10) show that grassy, painty and rancid flavors were present in all stored samples. Both OIV and FIV for "other" notes, such as stale, fruity, sour, bitter and rubbery, tended to be greater for oils treated with AP than those for the untreated control and BHA/BHT treated oils.

Generally, data obtained for the chemical and sensory analyses of canola oils stored in PVC bottles for up to 10 months indicate that the addition of either AP or BHA/BHT to canola oil was of little benefit in extending storage stability. However, due to the variability in the data obtained, conclusions cannot be made regarding the efficacy of either AP or BHA/BHT in canola oil stored under practical conditions.

Heating Studies

Extended Heating

Means and standard errors for chemical and instrumental analyses of canola oil subjected to extended heating at 185°C are presented in Tables 13 and 14. At each heating time throughout the 10 days of heating, no differences in the PV of oils (Table 13) due to treatment were found. Peroxide values increased to a maximum at 2.5 days and then decreased as heating time was lengthened. Since hydroperoxides decompose rapidly when exposed to heat (Gray, 1978; Fritsch et al., 1981), the low PV are as expected. Gwo et al. (1985) reported PV between 1.0 and 3.5 meq/kg for partially hydrogenated soybean oils, with and without AP, heated 10 to 11 hr/day for up to 10 days. Peled et al. (1975) noted low PV (between 1.0 and 4.0 meq/kg) for cottonseed oil heated at 180°C for up to 6 hr. Low PV were also found for palm olein heated at 185°C 4 hr/day for 2 days (Augustin and Berry, 1983b). Peroxide values are not generally used as a measure of frying fat

Table 13. Means[1] and standard errors for chemical analyses of canola oil, with and without antioxidant, following extended heating (185°C).

Test	Heating Time (days)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[2]
Peroxide Value (meq/kg)	1	2.28	2.22	2.32	2.38	2.38	0.07
	2.5	2.46	2.35	2.56	2.51	2.48	0.08
	5	2.02	1.95	1.95	2.10	2.00	0.10
	10	1.32	1.31	1.36	1.30	1.39	0.04
p-Anisidine Value	1	171.14	163.15	169.19	169.05	159.85	2.33
	2.5	219.13	216.38	220.35	219.12	217.73	0.30
	5	220.07	221.16	217.98	219.09	215.47	1.18
	10	191.91^a	183.75^b	184.98^b	184.99^b	178.50^b	1.57*
Conjugated Dienes (234 nm)	1	21.71	21.74	21.85	21.86	20.86	0.54
	2.5	31.14	31.63	30.80	33.40	31.58	0.59
	5	41.82	41.85	42.32	42.16	42.80	1.11
	10	44.35	45.12	45.12	44.67	44.85	0.95
Conjugated Trienes (268 nm)	1	6.17	6.25	6.12	6.18	5.98	0.10
	2.5	6.86	7.39	6.74	7.56	7.12	0.17
	5	8.07	8.18	8.10	8.13	8.47	0.30
	10	10.45	10.87	10.87	10.80	10.97	0.19

[1] Means for 1, 2.5 and 5 days are averages of 6 determinations (2 per each of 3 replicates); means for 10 days are averages of 4 determinations (2 per each of 2 replicates).

[2] Standard error of the mean.

[ab] Means within the same row sharing a common letter are not significantly different at P<0.05.

* Significant differences among canola oil treatments at P<0.05.

Table 14. Means and standard errors for physico-chemical analyses of canola oil, with and without antioxidant, following extended heating (185°C).

Test	Heating Time (days)	Canola Oil Treatment Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[1]
Color[2]	1	0.040	0.040	0.039	0.040	0.039	0.00
	2.5	0.102^{c}	0.107^{a}	0.103^{c}	0.104^{bc}	0.106^{ab}	0.00**
	5	0.232	0.240	0.240	0.234	0.236	0.02
	10	0.575	0.583	0.592	0.591	0.584	0.01
FFA (%)[2]	1	0.075	0.082	0.078	0.078	0.082	0.00
	2.5	0.235	0.245	0.255	0.210	0.233	0.01
	5	0.477	0.490	0.488	0.525	0.502	0.02
	10	0.945	0.892	0.918	0.975	0.940	0.05
Smoke Point[3] (°C)	1	201.3	203.3	204.7	206.0	204.7	1.10
	2.5	192.0	190.7	192.0	194.0	194.3	1.51
	5	178.3^{b}	181.0^{a}	181.0^{a}	180.7^{a}	183.0^{a}	0.58**
	10	168.5	169.0	171.5	173.0	170.5	1.18
Viscosity[3] (cps)	1	73.1	73.3	74.1	75.1	72.8	1.20
	2.5	106.9	108.3	108.8	105.7	107.9	1.78
	5	189.9	202.6	198.5	195.0	198.4	4.55
	10	564.2	597.8	597.6	620.4	586.0	10.64

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[1] Standard error of the mean.

[2] Means for 1, 2.5 and 5 days are averages of 6 determinations (2 per each of 3 replicates); means for 10 days are averages of 4 determinations (2 per each of 2 replicates).

[3] Means for 1, 2.5 and 5 days are averages of 9 determinations (3 per each of 3 replicates); means for 10 days are averages of 6 determinations (3 per each of 2 replicates).

[abc] Means within the same row sharing a common letter are not significantly different at P<0.05.

[**] Significant differences among canola oil treatments at P<0.01.

deterioration (Fritsch, 1981), as peroxides are very unstable at high temperatures and low values are obtained. In oil research, low PV are usually indicative of a fresh oil; thus the low PV of heated oils could be misleading if taken out of context.

At each of the heating times up to 5 days, no differences in AV were found among treatments (Table 13). After 10 days, the AV for the untreated control was higher ($P<0.05$) than those for the antioxidant treated oils. Aldehydic compounds, secondary oxidation products formed from the breakdown of peroxides, are measured by the AV test. Anisidine values for the samples were high after 1 day of heating and continued to increase during heating up to 5 days. However, after 10 days, AV declined and differences between the control and the antioxidant treated samples were determined. No reason is readily apparent for this finding. Data for the AV of oils subjected to extended heating conditions are lacking.

There were no significant differences in CD and CT (Table 13) at each of the heating times, during the 10 day period. In contrast, Gwo et al. (1985) found that the addition of 200 ppm AP to partially hydrogenated soybean oil decreased CD development after 10 days of heating. In the present storage studies, initial (0 time) CD and CT values for canola oils were approximately 4.0 and 0.90, respectively (see Tables 5 and 7, pages 56 and 71, respectively). Conjugated diene and CT values for canola oils increased rapidly during the first day of heating; throughout subsequent heating, the rate of increase slowed. For rice bran oil and palm olein, CD values increased rapidly during the first 20 hr of heating, after which the rate of increase slowed (Yoon et al., 1985). Peled et al. (1975) suggested that the change in the rate of CD formation could be explained by an equilibrium between the rate of CD formation and the rate at which CD formed polymers.

Few differences among the oil treatments were found for color, %FFA, smoke point and viscosity (Table 14). At 2.5 days, color values for T1, T3 and T4 were lower ($P<0.01$) than that for T2. As heating was prolonged, color values for all oil samples increased and no significant differences due to antioxidant treatment were determined. In contrast, Gwo et al. (1985) observed that 200 ppm AP reduced color development in a partially hydrogenated soybean oil, heated at 180°C, 10 to 11 hr/day for 10 days. Recently, Mancini-Filho et al. (1986) reported that the daily addition of 200 ppm AP increased color development in a partially hydrogenated soybean oil shortening in which French fries were fried for 6 days. In the present study, the addition of either AP or BHA/BHT to canola oil had little effect on color development.

At each heating time throughout the 10 days, the percentages of FFA in all oil treatments were similar and all increased to a maximum of approximately 0.90% at 10 days. The addition of either AP or BHA/BHT to canola oil had little effect on FFA formation during extended heating. In contrast, Mancini-Filho et al. (1986) noted that the daily addition of 200 ppm AP retarded FFA development in a partially hydrogenated soybean oil shortening used to fry French fries over a 6 day period.

Following 5 days of heating, smoke points for antioxidant treated oils (T2-T5) were significantly higher than that for the untreated control. At 10 days, the smoke points for all treatments were similar, however, those for T1 and T2 were below 170°C. This temperature (170°C), in conjunction with a concentration of petroleum ether insoluble oxidized fatty acids of 0.70% or greater, has been recommended by the German Society for Fat Research as a basis for discarding used frying fats (Billek et al., 1978).

Antioxidant treatment had no effect on the viscosity of canola oils heated for up to 10 days. As expected, oil viscosity increased as heating time was prolonged. Peled et al. (1975) reported large increases in viscosity for cottonseed oil heated for up to 6 hr. However, Stevenson et al. (1984a) observed only small increases in viscosity for a lightly hydrogenated canola oil used for frying French fries for up to 75 hr over a 10 day period.

In the present study, the relatively large increases in color and viscosity measurements, as heating time was extended, indicate that polymerization was a major factor in the oil degradation which occurred during extended heating. Increases in color and viscosity have been attributed to the polymerization which occurs when a fat or oil is heated (Fritsch et al., 1981; Stevenson et al., 1984b).

The addition of AP to canola oil subjected to extended heating was ineffective in retarding thermal degradation under these extreme heating conditions. This finding is in contrast to results reported by Gwo et al. (1985) for a similar study using a partially hydrogenated soybean oil. Gwo et al. (1985) suggested that the addition of 200 ppm AP to frying oils and fats may inhibit thermal degradation. However, Mancini-Filho et al. (1986) recently noted that the daily addition of AP to a partially hydrogenated soybean oil shortening used for frying, resulted in greater deterioration than that which occurred in untreated control samples.

The incorporation of BHA/BHT into canola oil subjected to extended heating was also ineffective in enhancing thermal stability. Similar conclusions were drawn by Rhee (1978), who added BHA/BHT to a soybean-cottonseed oil blend which was used for frying French fries during a total of 10 hr of heating.

In addition to the potential to enhance the heat stability of oils, antioxidants may also improve the stability of the resultant fried foods, due to carry-over effects. The carry-through properties of an antioxidant are important to its use in frying fats. Before conclusions as to the efficacy of AP in enhancing the extended heat stability of canola oil can be made, studies on the carry-through properties of AP are required.

Deep Fat Heating

Means and standard errors for chemical and instrumental analyses for canola oils subjected to deep fat heating for up to 60 min are given in Tables 15 and 16. At 0 min, data for each treatment are for oils which were heated to 185°C and immediately cooled.

Table 15. Means[1] and standard errors for chemical analyses of canola oil, with and without antioxidant, following deep fat heating (185°C).

Test	Heating Time (min)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[2]
Peroxide Value (meq/kg)	0	4.86^{a}	4.50^{a}	4.37^{a}	2.68^{b}	2.29^{b}	0.15***
	20	3.60^{b}	4.57^{a}	4.36^{a}	4.61^{a}	4.27^{a}	0.10***
	40	2.98^{b}	4.57^{a}	3.43^{ab}	4.09^{ab}	4.06^{ab}	0.29*
	60	2.98^{b}	3.95^{a}	3.06^{b}	3.16^{b}	4.26^{a}	0.10***
p-Anisidine Value	0	12.11^{a}	9.64^{b}	9.19^{b}	8.12^{b}	7.15^{b}	0.64**
	20	28.69^{a}	20.26^{bc}	23.55^{b}	20.73^{bc}	18.92^{c}	0.99***
	40	36.65^{a}	29.31^{c}	33.57^{b}	30.47^{c}	25.87^{d}	0.72***
	60	45.16^{a}	36.00^{c}	40.25^{b}	39.98^{b}	34.95^{c}	0.64***
Conjugated Dienes (234 nm)	0	4.36	4.27	4.30	4.21	4.17	0.05
	20	5.07^{a}	4.71^{b}	4.87^{ab}	4.71^{b}	4.62^{b}	0.06**
	40	5.46^{a}	5.08^{bc}	5.29^{ab}	5.16^{bc}	4.93^{c}	0.06**
	60	6.24^{a}	5.66^{c}	5.98^{b}	5.88^{b}	5.58^{c}	0.04***
Conjugated Trienes (268 nm)	0	0.78	0.78	0.79	0.78	0.78	0.02
	20	1.24^{a}	1.05^{ab}	1.05^{ab}	0.96^{b}	0.94^{b}	0.05*
	40	1.32^{a}	1.14^{b}	1.25^{a}	1.15^{b}	1.08^{b}	0.02***
	60	1.71^{a}	1.43^{c}	1.57^{b}	1.54^{b}	1.40^{c}	0.02**

[1] Means are averages of 6 determinations (2 per each of 3 replicates).

[2] Standard error of the mean.

[abcd] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

[*,**,***] Significant differences among canola oil treatments at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

Table 16. Means and standard errors for physico-chemical analyses of canola oil, with and without antioxidant, following deep fat heating (185°C).

Test	Heating Time (min)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[1]
Color[2]	0	0.009	0.009	0.009	0.009	0.009	0.00
	20	0.011	0.011	0.010	0.010	0.011	0.00
	40	0.013	0.013	0.012	0.012	0.012	0.00
	60	0.013	0.012	0.012	0.012	0.012	0.00
FFA (%)[2]	0	0.027^{b}	0.038^{a}	0.026^{b}	0.028^{b}	0.040^{a}	0.00***
	20	0.028^{b}	0.040^{a}	0.027^{b}	0.028^{b}	0.040^{a}	0.00***
	40	0.028^{b}	0.037^{a}	0.028^{b}	0.028^{b}	0.038^{a}	0.00***
	60	0.030^{b}	0.041^{a}	0.032^{b}	0.033^{b}	0.041^{a}	0.00***
Smoke Point[3] (°C)	0	217.7	216.0	216.3	218.0	217.3	0.76
	20	212.3	213.7	214.7	213.7	216.0	1.21
	40	211.3	211.3	211.3	213.3	215.0	0.89
	60	209.7^{b}	209.7^{b}	215.0^{a}	213.7^{ab}	213.7^{ab}	0.99*
Viscosity[3] (cps)	0	56.1	56.1	56.0	56.1	56.4	0.30
	20	57.5	57.1	57.3	57.1	56.8	0.27
	40	57.3	57.5	56.9	57.4	56.6	0.29
	60	57.3	57.5	58.0	57.8	57.0	0.47

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[1] Standard error of the mean.

[2] Means are averages of 6 determinations (2 per each of 3 replicates).

[3] Means are averages of 9 determinations (3 per each of 3 replicates).

[ab] Means within the same row sharing a common letter are not significantly different at P<0.05.

*,*** Significant differences among canola oil treatments at P<0.05 and P<0.001, respectively.

Initially (0 min), PV (Table 15) for T4 and T5 were similar and lower (P<0.001) than those for T1, T2, and T3. At 20 min, the PV for T1 was significantly lower than those for T2, T3, T4 and T5, which were similar. After 40 min, the PV for T1 was lower (P<0.05) than that for T2, but neither T1 nor T2 differed from those for the AP treated oils. At 60 min, the PV for T1, T3 and T4 were similar and significantly lower than those for T2 and T5. Data for PV at 0 min, indicate that 200 ppm AP significantly lowered the amount of peroxides present in canola oils heated to 185°C and cooled. At each subsequent heating time, PV for the untreated control tended to be lower than those for the antioxidant treated oils. Fritsch (1981) noted that peroxides may increase after a sample is taken from a heated fat, before it is analyzed. Since peroxides are very unstable when exposed to heat, the use of PV as a measure of heated oil quality is not recommended.

At 0 min, the AV (Table 15) for the untreated control was higher (P<0.01) than those for the antioxidant treated oils, which were similar. After 20 min, the AV for T1 was significantly higher (P<0.001) than that for T3, which in turn was higher than the AV of T5. At 40 min, the AV for T5 was lower (P<0.001) than those for T2 and T4, which were similar and lower than that for T3, which in turn was lower than that for T1. After 60 min, the AV for T2 and T5 were similar and lower (P<0.001) than those for T3 and T4, which were lower than that for T1. As expected, AV increased as heating time was lengthened.

At each time throughout the entire heating period, all antioxidant treated oils contained significantly lower amounts of aldehydes (as measured by AV) than the untreated control. Generally, the incorporation of either BHA/BHT (T2) or 200 ppm AP + CA (T5) in canola oils resulted in similar and significantly lower amounts of aldehydes than did other antioxidant treatments. This supports the finding of Hawrysh (1987), who reported that BHA/BHT inhibited the development of aldehydes in canola oils subjected to deep fat heating conditions. No reports on aldehyde development in AP treated oils subjected to heat have been found.

Conjugated diene values at 0 min were similar for all treatments. However, after 20 min, the CD value for T1 was higher ($P<0.01$) than those for T2, T4 and T5, which were similar. At 40 min, the CD value for T5 was significantly lower than that for T1 and T3, which were similar. After 60 min, CD values for T2 and T5 were the lowest, followed by those for T3 and T4, with the CD value for T1 being the highest. Although differences in CD among oil treatments were significant, the differences were relatively small. Following 60 min of heating, all antioxidant treated oils were lower in CD than the untreated oil. The addition of either BHA/BHT (T2) or 200 ppm AP + CA (T5) to canola oil resulted in lower amounts of CD than were present in the other antioxidant treated oils (T3 and T4). Similar CD values were noted by Hawrysh (1987) for untreated and BHA/BHT treated canola oils subjected to deep fat heating. Studies of CD in heated, AP treated canola oils are unavailable.

Conjugated triene values for all oil treatments were similar at 0 min. At 20 min, CT values for T4 and T5 were significantly lower than that for T1. After 40 min, CT values for T2, T4, and T5 were similar and lower (P<0.001) than those for T1 and T3. At 60 min, T2 and T5 had CT values that were similar and lower (P<0.01) than those for T3 and T4, which were lower than that for T1. As heating time was extended, only small increases in CT were determined. Generally, the BHA/BHT (T2) and the 200 ppm AP + CA (T5) treated oils showed the smallest increases in CT during heating. Hawrysh (1987) also reported small increases in the CT values of canola oils subjected to deep fat heating. Information on the formation of CT in AP treated canola oils subjected to heat is lacking.

For each time during the 60 min of heating, no differences among oil treatments were found for color measurements (Table 16). An increase in heating time from 0 to 60 min, resulted in only slight darkening in oil color. This finding supports the research of Hawrysh (1987), who found only slight increases in oil color for untreated, BHA/BHT and TBHQ treated canola oils subjected to deep fat heating.

At each heating time, %FFA (Table 16) for T2 and T5 were similar and higher (P<0.001) than those for T1, T3 and T4. The presence of 50 ppm CA in T2 and T5 may account for the higher %FFA obtained for these treatments. The measurement of FFA does not distinguish between acidity contributed by FFA and that supplied by other acidic compounds, and the addition of acidic compounds, such as CA, to fats and oils, will contribute apparent FFA (Sherwin, 1972). During the 60 min heating period, the %FFA content of all treatments increased slightly, however, the differences due to treatment appear to result from the presence of

CA and not antioxidants. These effects of CA on %FFA were not observed in samples exposed to extended heating (Table 13, page 88) as CA decomposes when exposed to high temperatures for an extended time.

For each heating time up to 40 min, smoke points (Table 16) for all oil treatments were similar. At 60 min, the smoke point for T3 was similar to those for T4 and T5, but was significantly higher than those for T1 and T2, which were also comparable to T4 and T5. As expected, smoke points dropped as heating time was extended. Following 60 min of deep fat heating, the smoke points of all oil samples were much higher than the temperature (170°C) recommended by the German Society for Fat Research (Billek et al., 1978) as a basis for discarding used fats.

No differences in sample viscosity (Table 16) due to antioxidant treatment were found at each time throughout the 60 min. Generally, only slight increases in oil viscosity were found as heating time was extended. In a related study, Hawrysh (1987) also reported only slight increases in viscosity during 60 min of deep fat heating of canola oils.

In this study, chemical and instrumental data collected during deep fat heating (with conditions similar to those used in the home) indicate that both BHA/BHT and 200 ppm AP decreased the thermal degradation of heated canola oils. Data for AV, CD and CT indicate that the addition of either BHA/BHT or 200 ppm AP to canola oil, decreased the formation of aldehydes, conjugated diene and conjugated triene hydroperoxides during deep fat heating. However, the addition of either BHA/BHT or AP to canola oil tended to have little effect on color, smoke point and viscosity. In the present study, the small increases in color and viscosity data, for all oil treatments, as heating time was extended, indicate that polymerization may not have been a major factor in the oil degradation which occurred during simulated home-style deep fat heating. These findings indicate that after 60 min of deep fat heating, all oils were of fairly good quality.

Data for the sensory analyses of canola oil subjected to deep fat heating for up to 60 min are presented in Table 17. At each heating period, odor scores for all oil treatments were similar and significantly lower than that of the hidden control. The flavor scores for all of the heated oils were significantly lower than those for the hidden controls. At 0, 40 and 60 min, flavor scores for all heated oil samples were similar. After 20 min, the flavor score for T2 was higher ($P<0.001$) than that for T1; however, both were comparable in flavor to T3, T4 and T5. Following 60 min of heating, odor and flavor scores were indicative of mild to moderate intensities.

Odor and flavor intensity values for canola oil subjected to deep fat heating are presented in Appendices 11 and 12, respectively. Throughout sensory testing, T6 (the hidden control) was considered bland. Generally, fishy odors were present in all heated samples after 20 min of heating. At 60 min, fishy OIV for T2 and T4 dropped while those for other treatments either remained stable or increased slightly. Heated and painty odors were noted in all treatments and their intensity increased as heating time was extended. Rancid odors developed in T1 and T4 following 20 min and were also present in other samples after 40

Table 17. Means and standard errors for odor and flavor intensity scores for canola oil, with and without antioxidant, following deep fat heating (185°C).

		Canola Oil Treatment						
Characteristic	Heating Time (min)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)	SEM[1]
Overall Odor	0	6.7^{b}	6.7^{b}	6.7^{b}	7.1^{b}	6.3^{b}	9.5^{a}	0.37**
Intensity[2]	20	5.0^{b}	6.5^{b}	5.4^{b}	6.0^{b}	5.4^{b}	9.8^{a}	0.38***
	40	5.4^{b}	6.2^{b}	5.5^{b}	5.5^{b}	5.8^{b}	9.5^{a}	0.28***
	60	4.8^{b}	5.7^{b}	5.3^{b}	5.5^{b}	5.4^{b}	9.6^{a}	0.25***
Overall Flavor	0	5.9^{b}	6.2^{b}	6.2^{b}	7.3^{b}	6.3^{b}	9.8^{a}	0.38***
Intensity[2]	20	5.1^{c}	6.5^{b}	5.8^{bc}	6.1^{bc}	5.3^{bc}	10.0^{a}	0.28***
	40	5.6^{b}	6.1^{b}	6.0^{b}	5.5^{b}	5.5^{b}	10.0^{a}	0.33***
	60	5.4^{b}	5.6^{b}	5.5^{b}	5.5^{b}	5.7^{b}	9.8^{a}	0.27***

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[1] Standard error of the mean.

[2] Ten point scale, 10=maximum. Lower values indicate increasing odor and flavor intensity. Means are averages of 24 scores (8 panelists, 3 replications).

[abc] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

[**,***] Significant differences among canola oil treatments at $P<0.01$ and $P<0.001$, respectively.

min. Fishy, heated, painty and rancid flavors were detected throughout heating. At 0 min, painty OIV and FIV for T4 and T5 tended to be lower than for other oil samples. But, the addition of either BHA/BHT or AP to canola oil did not inhibit the development of fishy, heated, painty and rancid odors and flavors in oils during further heating.

Sensory data (Table 17) show that the changes due to deep fat heat treatment occur rapidly during initial heating. Odor and flavor intensity scores for all oil samples at 0 min were significantly lower than that for the hidden control. Further heating of the oils for up to 60 min, resulted in small decreases in intensity scores. The addition of either BHA/BHT or AP to canola oil was ineffective in delaying the development of prominent odor and flavor notes. Generally, data from trained panelists indicate that BHA/BHT and AP did not improve the sensory quality of canola oils during deep fat heating at 185°C.

In the present study, AP and BHA/BHT were relatively ineffective in enhancing the sensory quality of canola oil heated under deep fat conditions. This finding supports the research of Vaisey-Genser and Ylimaki (1985) who reported that BHA/BHT treated canola oils, when heated, had heated oil odors comparable in intensity to that for untreated canola oils. Similar observations were made by Hawrysh (1987). In contrast, Mounts (1979) concluded that BHA/BHT improved the room odor scores of heated soybean oils. Research on the sensory quality of heated AP treated canola oils is needed.

Deep fat frying is a popular method of food preparation in the home. A consumer survey (Shaykewich and Vaisey-Genser, 1982) has shown that, in western Canada, 40% of households deep fry and that oil is the most common fat used for this purpose. During deep fat heating of oils, a number of reactions occur which alter the physical, chemical and sensory properties of oils. In the present study, AP was added to canola oil in an attempt to decrease the changes which occur when canola oil is heated under deep fat frying conditions used in the home. Data indicate that while AP was effective in reducing oil changes measured by physicochemical methods, AP was ineffective in enhancing the odor and flavor stability of canola oils subjected to home-type deep fat heating conditions.

Shallow Pan Heating

Data for chemical and instrumental analyses of canola oils subjected to shallow pan heating are presented in Tables 18 and 19. At 0 min, data for each treatment are for oils which were heated to 185°C and immediately cooled.

At 0 min, PV (Table 18) for T1 and T2 were significantly higher than those for T3, T4 and T5 (the AP treated oils), with the PV for T5 being lower than that for T3. At each subsequent time, no differences in PV due to antioxidant treatment were found. The greatest increase in the PV of all treatments occurred between 0 and 6 min of heating. The PV for T1 at 12 min, was slightly lower than that obtained at 6 min; however, those for T2-T5 increased slightly as heating time increased from 6 to 12 min. The decrease in the PV of T1 during heating from 6 to

Table 18. Means[1] and standard errors for chemical analyses of canola oil, with and without antioxidant, following shallow pan heating (185°C).

Test	Heating Time (min)	Canola Oil Treatment Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[2]
Peroxide	0	8.05^{a}	7.50^{a}	4.94^{b}	2.90^{bc}	2.05^{c}	0.69***
Value	6	14.08	14.26	13.87	13.37	13.37	0.27
(meq/kg)	12	13.85	15.29	14.24	14.53	15.28	0.32
p-Anisidine	0	10.44^{a}	9.4^{ab}	7.03^{bc}	5.76^{c}	4.45^{c}	0.76**
Value	6	41.10^{a}	33.81^{b}	34.04^{b}	32.09^{b}	29.80^{b}	1.63*
	12	64.85^{a}	59.18^{ab}	60.82^{ab}	57.51^{ab}	54.79^{b}	1.73*
Conjugated	0	4.32^{a}	4.29^{a}	4.09^{b}	4.00^{b}	3.92^{b}	0.05**
Dienes	6	5.50	5.24	5.34	5.24	5.18	0.08
(234 nm)	12	6.06^{a}	5.73^{b}	5.72^{b}	5.70^{b}	5.62^{b}	0.06**
Conjugated	0	0.75^{a}	0.74^{a}	0.69^{b}	0.67^{b}	0.67^{b}	0.01***
Trienes	6	1.35	1.25	1.24	1.19	1.15	0.04
(268 nm)	12	1.70^{a}	1.57^{b}	1.58^{b}	1.54^{b}	1.49^{b}	0.03*

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[1] Means are averages of 6 determinations (2 per each of 3 replicates).

[2] Standard error of the mean.

[abc] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

*,**,*** Significant differences among canola oil treatments at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

Table 19. Means and standard errors for physico-chemical analyses of canola oil, with and without antioxidant, following shallow pan heating (185°C).

Test	Heating Time (min)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	SEM[1]
Color[2]	0	0.010	0.010	0.009	0.009	0.009	0.00
	6	0.014	0.014	0.013	0.013	0.013	0.00
	12	0.017	0.017	0.016	0.015	0.016	0.00
FFA (%)[2]	0	0.025^{b}	0.034^{a}	0.022^{b}	0.026^{b}	0.038^{a}	0.00***
	6	0.034^{ab}	0.040^{a}	0.030^{b}	0.033^{ab}	0.041^{a}	0.00*
	12	0.040^{b}	0.046^{a}	0.039^{b}	0.042^{ab}	0.046^{a}	0.00*
Smoke Point[3] (°C)	0	217.3	217.0	217.7	219.3	219.0	0.56
	6	214.0^{b}	214.7^{b}	216.3^{a}	216.7^{a}	216.0^{a}	0.38**
	12	208.7^{b}	211.7^{ab}	210.7^{ab}	212.3^{a}	213.3^{a}	0.75*
Viscosity[3] (cps)	0	56.8	56.8	56.6	56.9	56.9	0.26
	6	58.3	58.0	57.9	57.8	57.9	0.18
	12	59.1	59.0	59.0	59.5	59.7	0.28

[1] Standard error of the mean.

[2] Means are averages of 6 determinations (2 per each of 3 replicates).

[3] Means are averages of 9 determinations (3 per each of 3 replicates).

[ab] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

*,**,*** Significant differences among canola oil treatments at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

12 min may be due to the degradation of peroxides, as peroxides are very unstable when exposed to heat (Fritsch, 1981).

At 0 min, AV (Table 18) for T3, T4 and T5 were similar and lower (P<0.01) than that for T1. At 6 min, the AV for T1 was significantly greater than those for T2, T3, T4 and T5, which were similar. At 12 min, the AV for T5 was lower (P<0.05) than that for T1. As expected, AV increased as heating time was extended. Data for AV show a very rapid development of aldehydes in all oil treatments during shallow pan heating. Similar increases in the AV of antioxidant treated canola oils subjected to shallow pan heating were noted by Hawrysh (1987). In the current study, the presence of BHA/BHT in canola oil did not decrease the development of aldehydes. This finding agrees with that of Hawrysh (1987), who also noted that BHA/BHT was ineffective in inhibiting aldehyde development in canola oils during shallow pan heating.

The initial (0 min) CD and CT values (Table 18) for the AP treated oils were similar and significantly lower than those for T1 and T2. At 6 min, there were no differences in either CD or CT values. However, at 12 min, the CD and CT values for T1 were significantly higher than those for T2-T5, which were similar. Following 12 min of shallow pan heating, data from CT and CD analyses indicate that BHA/BHT and AP had a significant but slight effect on decreasing the development of conjugated diene and triene hydroperoxides in canola oils. In part, this finding agrees with the conclusions of Hawrysh (1987), who reported differences similar to those found in the present study between the CD values of BHA/BHT treated and untreated canola oils subjected to shallow pan heating. In contrast to the present study, Hawrysh (1987) noted no differences between the CT values of the same oil treatments. Information on CD and CT development in AP treated canola oils subjected to shallow pan heating is unavailable.

At each heating time, no differences among oil treatments were found for color and viscosity (Table 19). As heating time was extended, color intensity and viscosity increased slightly. Small increases in color and viscosity indicate that only a limited amount of polymerization occurred during shallow pan heating. Reports on the viscosity and color of AP treated canola oils after shallow pan heating are lacking.

At 0 min, the percentages of FFA (Table 19) in T2 and T5 were similar and significantly higher than those for T1, T3 and T4. At 6 min, the FFA content of T2 and T5 was similar to those for T1 and T4, but higher ($P<0.05$) than that for T3. After 12 min, the FFA content of T2 and T5 was similar to that for T4, but higher than those for T1 and T3. As dicussed previously, the presence of CA in T2 and T5 probably accounts for the high apparent %FFA.

The smoke points (Table 19) of all oils were similar at 0 min. However, at 6 min, smoke points for T3-T5 were higher ($P<0.01$) than those for T1 and T2. At 12 min, the smoke points for T4 and T5 were similar and remained higher than that for T1. Following 12 min of shallow pan heating, the smoke point for each of the oil treatments was above 170°C, which is the temperature used as a criteria for discarding used frying fats in Germany (Billek et al., 1978). Similar decreases in the smoke points of canola oils subjected to shallow pan heating were reported by Hawrysh (1987).

In this study, chemical and instrumental data collected during shallow pan heating of canola oils, at 185°C for 12 min, indicate that the addition of either BHA/BHT or AP to canola oil, had a slight but significant effect in improving the thermal stability of the oil. Generally, data for AV, CD, CT and smoke points, indicate that additions of either BHA/BHT or AP increased the thermal stability of canola oil. Data for PV and %FFA are difficult to interpret due to the intrinsic factors discussed earlier.

Data for the sensory analyses of canola oil subjected to shallow pan heating are shown in Table 20. At each time during shallow pan heating, odor scores for all of the heated oils (T1-T5) were significantly lower than that of the hidden control (T6). At 0 min, the odor score for T5 was higher ($P<0.001$) than that for T1. After 6 and 12 min, odor scores for all heated oils (T1-T5) were similar. At 0 min, flavor scores for all of the heated oils (T1-T5) were similar, and those for T4 and T5 were the same as T6. At each subsequent heating time, flavor scores for all of the heated oil samples (T1-T5) were significantly lower than that of the hidden control. At 6 min, flavor scores for T2 and T5 were similar to those of T3 and T4, but higher ($P<0.001$) than that for T1. At 12 min, flavor scores for all heated oils were similar. Following 12 min, odor and flavor scores were characteristic of slightly intense on a 10-point scale, where 10=bland and 1=extreme.

Table 20. Means and standard errors for odor and flavor intensity scores for canola oil, with and without antioxidant, following shallow pan heating (185°C).

Characteristic	Heating Time (min)	Canola Oil Treatment						
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)	SEM[1]
Overall Odor	0	7.3^{c}	7.8^{bc}	7.9^{bc}	7.7^{bc}	8.5^{b}	9.5^{a}	0.24**
Intensity[2]	6	6.4^{b}	7.1^{b}	7.3^{b}	7.7^{b}	7.2^{b}	9.5^{a}	0.28***
	12	6.5^{b}	7.0^{b}	6.4^{b}	6.7^{b}	6.6^{b}	9.7^{a}	0.27***
Overall Flavor	0	7.2^{b}	7.4^{b}	7.8^{b}	8.2^{ab}	8.1^{ab}	9.3^{a}	0.31**
Intensity[2]	6	6.5^{c}	7.5^{b}	7.1^{bc}	7.2^{bc}	7.4^{b}	9.8^{a}	0.19***
	12	6.7^{b}	6.9^{b}	6.5^{b}	6.8^{b}	6.7^{b}	9.8^{a}	0.28***

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[1] Standard error of the mean.

[2] Ten point scale, 10=maximum. Lower values indicate increasing odor and flavor intensity. Means are averages of 24 scores (8 panelists, 3 replications).

[abc] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

[**,***] Significant differences among canola oil treatments at $P<0.01$ and $P<0.001$, respectively.

Odor intensity values for canola oils subjected to shallow pan heating are presented in Appendix 13. Fishy odors were present in T1 following 6 min and they were noticeable in T3-T5 at 12 min of heating. Fishy odors were not found in T2 throughout heating. At 0 min, heated odors were noted in T1 and T2. At 6 and 12 min, heated odors were detected in all heated oil samples; however, heated OIV for T4 and T5 were lower than those for other treatments. Painty odors developed in T1-T3 at 0 min. After 6 and 12 min, painty odors were present in all heated oils; however, T4 and T5 had lower OIV for painty notes than did the other oil treatments. Rancid odors developed in T1 and T5 following 6 min. At 12 min, rancid odors were detected in all heated oils.

Flavor intensity values for canola oils exposed to shallow pan heating are presented in Appendix 14. Fishy flavors developed in T1 and T4 after 12 min of heating, but were not apparent in other treatments. At 0 min, heated flavors were present in T1 and T2 and developed in the other treatments after additional heating. Painty flavors were noted in T1-T3 at 0 min. At 6 and 12 min, painty flavors were detected in all heated oils. Rancid flavors were present at 0 min in T5, and at 6 and 12 min in T1, T2, T4 and T5. These FIV support panelists' OIV for oils subjected to shallow pan heating.

Sensory data (Table 20) generally show few differences between the antioxidant treated canola oils and the untreated canola oil. The addition of 200 ppm AP to canola oil did improve flavor scores at 0 min; however, differences in oil samples due to antioxidant treatment were not found during further heating. The greatest decrease in odor and flavor intensity scores of the oil samples, as compared to the hidden control, occurred during the initial heating to 185°C. Small decreases in odor and flavor intensity scores of the oils were determined following 6 and 12 min of heating. However, the addition of 200 ppm AP to canola oil tended to delay the development of heated and painty odor and flavor notes. The presence of BHA/BHT in canola oil inhibited the development of fishy odor notes during shallow pan heating.

Generally, the sensory quality of canola oil was not influenced by the antioxidant treatments investigated in the present shallow pan heating study. Reports in the literature on the effects of AP on the sensory quality of oils subjected to shallow pan heating are lacking.

Pan frying is a popular method of food preparation in both household and institutional settings. As previously discussed, much research (Fritsch et al., 1975; Blumenthal et al., 1976; Nawar, 1978; Bracco, 1981; Gere, 1982; Thompson and Aust, 1983) has been reported on the thermal degradation of oils heated under deep frying conditions. Information on the thermal degradation which occurs when an oil or fat is subjected to shallow pan heating is limited.

Shallow pan heating conditions involve a much higher specific surface than that which is found in deep fat heating. The oil surface area which is exposed to air is a major factor in the thermal stability of a fat or oil (Rock and Roth, 1964; Bracco et al., 1981; Gere, 1982). In the present study, the thermal degradation of the oil samples which occurred during 12 min of shallow pan heating (2.89 cm^2/g specific surface) was generally greater than that which took place during 60 min of deep fat heating (0.189 cm^2/g specific surface). Similar conclusions were noted by Hawrysh (1987) for antioxidant treated canola oils subjected to both deep fat and shallow pan heating.

Generally, the results of chemical analyses show that AP and BHA/BHT improved canola oil stability during shallow pan heating. However, trained panel analyses indicate that neither BHA/BHT nor AP improved the sensory quality of canola oils subjected to shallow pan heating.

Correlations for Deep Fat and Shallow Pan Heating

Pearson correlation coefficients obtained to assess the relationship between sensory and chemical data from deep fat and shallow pan heating are presented in Table 21. For deep fat heating, correlations between odor scores and PV, AV, CD, CT, color, smoke point and viscosity and between flavor scores and AV, CD, and CT are significant. All coefficients for shallow pan heating are significant. Although a number of correlations are significant, none can be classified as excellent ($r \geq 0.76$) (Leporiere, 1976).

The majority of the coefficients obtained from deep fat heating were below 0.50, except those for odor scores and AV, CD, and CT. A correlation coefficient between 0.26 and 0.50 is considered to be fair (Leporiere, 1976). For deep fat heating, the correlations between chemical data and odor scores were higher than those for chemical data and flavor scores.

Table 21. Pearson correlation coefficients (r) between sensory evaluation data and chemical data for deep fat and shallow pan heating.

Test	Deep Fat Heating (N=60)		Shallow Pan Heating (N=45)	
	Odor Scores	Flavor Scores	Odor Scores	Flavor Scores
Peroxide Value	0.29*	0.11	-0.67***	-0.64***
Anisidine Value	-0.60***	-0.37**	-0.71***	-0.67***
CD (234 nm)	-0.60***	-0.41***	-0.58***	-0.69***
CT (268 nm)	-0.57***	-0.35**	-0.67***	-0.70***
Color	-0.43***	-0.22	-0.63***	-0.50***
%FFA	-0.08	-0.03	-0.42**	-0.39**
Smoke Point	0.32*	0.19	0.66***	0.69***
Viscosity	-0.34**	-0.23	-0.69***	-0.61***

*,**,*** Significant at $P<0.05$, $P<0.01$, and $P<0.001$, respectively.

Correlation coefficients obtained for shallow pan heating were generally good with the exception of those for %FFA. Differences between coefficients for odor scores and those for flavor scores were small.

Reports in the literature on correlations between sensory and chemical data for heated fats are limited. Dobbs et al. (1978) reported good correlations between TBA numbers (as measured at 528 nm) and odor scores for heated rapeseed oil. In the present study, good correlations were obtained between AV and odor scores. Since determinations of both TBA numbers and AV measure the presence aldehydes, similarities between the correlations of TBA numbers and odor scores and that for AV and odor scores may exist.

5. SUMMARY AND CONCLUSIONS

Canola oil was subjected to 5 treatments; an untreated control (T1), canola oil treated with BHA/BHT + CA (T2), canola oil treated with 100 ppm AP (T3), canola oil treated with 200 ppm AP (T4), and canola oil treated with 200 ppm AP + CA (T5). The exact composition of each treatment is given in Table 3, page 36. Each canola oil treatment was subjected to 3 storage experiments (Schaal oven, fluorescent light and practical storage) and 3 heating experiments (extended, deep fat and shallow pan heating). The effects of treatment on the storage and heat stability of canola oil were studied using chemical and instrumental measurements and sensory evaluations by a trained panel.

The results from chemical and sensory analyses indicate that AP was effective in retarding autoxidation of canola oils subjected to accelerated storage at 65°C for up to 16 days (Schaal oven test). Following 16 days of storage, data for canola oil containing 200 ppm AP (T4 and T5) for PV, TBA1, TBA2, CD and CT were significantly lower than those for untreated canola oil, canola oils treated with BHA/BHT and canola oil treated with 100 ppm AP. Trained panel odor and flavor intensity scores for T4 and T5 tended to be higher ($P<0.001$) than those for T1-T3. The addition of 200 ppm AP to canola oil delayed and decreased the development of painty odors and flavors during Schaal oven storage. Data indicate that 100 ppm AP was effective in extending the stability of canola oils stored at 65°C for up to 8 days. Increasing the concentration of AP in canola oils lengthened the induction period.

The additon of CA to canola oil containing 200 ppm AP did not improve autoxidative stability during storage at 65°C.

The commonly used combination of BHA/BHT was ineffective in extending the storage stability of canola oil during Schaal oven tests. Chemical data for canola oil treated with BHA/BHT (T2) were similar to that for the untreated control (T1). Trained panel data indicated that the addition of BHA/BHT to canola oil had a slight but generally nonsignificant effect on odor and flavor intensity scores, as compared to the untreated control.

Results from the accelerated storage test in which oils were exposed to fluorescent light (7532 lux) at 25°C for up to 24 hr, indicate that 200 ppm AP had a slight but significant effect on extending the photooxidative stability of canola oils. Data for PV, TBA1, TBA2 and CD indicate that the addition of AP (100 or 200 ppm) improved the photooxidative stability of canola oil as compared to both the untreated control and oil treated with BHA/BHT. The addition of 200 ppm AP tended to retard photooxidation as compared to 100 ppm AP, although differences were not always significant. The incorporation of 200 ppm AP into canola oil improved odor scores following 24 hr of exposure to fluorescent light, but had no effect on flavor scores. Ascorbyl palmitate (200 ppm) also delayed the development of rancid odors in canola oil during fluorescent light exposure. The addition of CA to canola oil containing 200 ppm AP decreased the development of monounsaturated aldehydes (as indicated by lower TBA1 numbers) during the fluorescent light test; however, CA addition had no effect on other chemical and sensory parameters examined. As with Schaal oven storage, the addition of BHA/BHT generally did not enhance the photooxidative stability of canola oil.

Data obtained from the storage of canola oil in PVC bottles at room temperature under fluorescent light (1400 lux) for 12 hr/day (practical storage) indicate that the addition of either BHA/BHT or AP to canola oil had little effect on chemical and sensory data. Considering the large variability in the data, conclusions regarding the effects of either AP or BHA/BHT on the storage stability of canola oil under practical conditions cannot be made. Further research on the practical storage stability of AP treated canola oil is necessary before conclusions can be drawn. Investigations into the cause of the erratic values obtained in the present study would be benefical to further studies of antioxidant activity in oils during practical storage. Comparisons of the stability of AP treated canola oils stored in a variety of packages, under different lighting conditions, would help oil producers choose appropriate containers for canola oils.

In the present study, comparisons were not possible between the quality of canola oils obtained from accelerated tests with that of oil acquired from practical storage experiments. There is evidence that suggests that the changes which occur during accelerated storage tests are not indicative of those which take place during practical storage (Ragnarsson et al., 1977; Kiritsakis et al., 1983; Dziedizic and Hudson, 1984). Research designed to compare the quality of canola oils exposed to different storage conditions is needed.

Data obtained from extended heating (10 hr/day for up to 10 days) of canola oil indicate that neither AP nor BHA/BHT was effective in enhancing the thermal stability of canola oil. The oils obtained after 10 days of extended heating would not be suitable for use as a frying medium. The extreme heating conditions used in this study can be used as an indication of the heat stability of vegetable oils. Research on the use of AP treated canola oils subjected to extended frying conditions is necessary to fully evaluate the efficacy of AP in improving the heat stability of canola oils used for deep fat frying. Studies of the carry-through properties for foods fried in AP treated canola oils are justified as AP has been reported to provide carry-over protection for potato chips fried in AP treated cottenseed oils (Cort, 1974).

Generally, results of chemical analyses for deep fat heating (up to 60 min) and shallow pan heating (up to 12 min) of canola oils, indicate that AP and BHA/BHT enhanced the thermal stability of canola oils. Results from deep fat heating, following 60 min, for AV, CD and CT for BHA/BHT and AP treated canola oils were significantly lower than those for the untreated control. Data from shallow pan heating followed similar trends. Sensory data for both deep fat and shallow pan heating, following 60 and 12 min, respectively, indicated no differences in odor and flavor intensity scores due to antioxidant treatment. During shallow pan heating, the addition of 200 ppm AP delayed the development of heated and painty odors and flavors in canola oils. The oils obtained following 60 and 12 min of deep fat and shallow pan heating, respectively, were of relatively good quality, although some oil degradation was apparent.

Data collected in the present studies on the storage and heat stability of AP treated canola oils, indicate that the addition of 200 ppm AP to canola oil may be benefical in improving oil stability. Results from accelerated storage and deep fat and shallow pan heating experiments show significant improvements in canola oil quality when 200 ppm AP is incorporated.

Further research on canola oil stability under a variety of storage, heating and frying conditions is necessary to ensure consumers and producers of high quality canola oil and canola oil products. The evaluation of antioxidants, such as AP is essential in this regard. Alternate methods of incorporating AP into oils should be investigated, as ethanol was found to be an unsuitable carrier. Research examining the efficacy of greater concentrations of AP than were used in the present study is essential, as increasing concentrations of AP have been reported to increase stability in other oils (McConnell and Esselsen, 1947; Pongracz, 1973; Cort, 1974). Research on the carry-through properties of AP in products which are prepared in AP treated canola oils is necessary to fully evaluate the efficacy of AP in extending canola oil heat stability. Studies on the synergistic effects of AP and tocopherols in canola oil may be warranted, as it has been suggested (Pongracz, 1973; Klaui, 1976) that these compounds display very powerful synergism.

Studies on the use of GLC methods to evaluate the flavor characteristics of canola oil are required. The relationship between GLC and sensory evaluation data obtained from antioxidant treated canola oils needs to be characterized. Studies are currently underway to examine the relationship between the trained panel data collected in the present study and GLC analyses of AP treated canola oils.

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Appendix 1. Descriptive terms provided to assist panelists in the evaluation of the odor and flavor characteristics of oxidized canola oils.

ODOR/FLAVOR DESCRIPTIONS

NUTTY

BUTTERY

SWEET

CHEMICAL
METALLIC

GRASSY
WEEDY

PAINTY
TURPENTINE

FISHY

COD LIVER OIL

OXIDIZED
RANCID
OLD OIL

HEATED

Appendix 2. Scorecards used for the assessment of oxidized canola oil samples.

NAME ______________________________ DATE ________________

SAMPLE CODE							
OVERALL INTENSITY	ODOR	ODOR	ODOR	ODOR	ODOR	ODOR	ODOR
10 bland							
9 trace							
8 faint							
7 slight							
6 mild							
5 moderate							
4 definite							
3 strong							
2 very strong							
1 extreme							

ODOR DESCRIPTION BLANK=NONE 1=VERY SLIGHT 3=MODERATE 5=VERY STRONG

BUTTERY							
FISHY							
GRASSY							
NUTTY							
PAINTY							
RANCID							
SWEET							
OTHER (specify)							

COMMENTS:

Appendix 2. Continued.

NAME ______________________________ DATE ______________

SAMPLE CODE							
OVERALL INTENSITY	FLAVOR	FLAVOR	FLAVOR	FLAVOR	FLAVOR	FLAVOR	FLAVOR
10 bland							
9 trace							
8 faint							
7 slight							
6 mild							
5 moderate							
4 definite							
3 strong							
2 very strong							
1 extreme							

FLAVOR DESCRIPTION BLANK=NONE 1=VERY SLIGHT 3=MODERATE 5=VERY STRONG

BUTTERY							
FISHY							
GRASSY							
NUTTY							
PAINTY							
RANCID							
SWEET							
OTHER (specify)							

COMMENTS:

Appendix 3. Instructions given to trained panelists for the evaluation of canola oils.

EVALUATION PROCEDURE FOR OILS

PLEASE EVALUATE THE SAMPLES IN THE ORDER INDICATED

RETASTE AS NEEDED

1. Rinse your mouth with water.

2. Evaluate ODOR of all samples:

   a) Shake sample vial.

   b) Bring sample vial to nose, remove cap and sniff using short sniffs (3-4).

   c) Recap vial.
   RECORD INTENSITY AND ODOR DESCRIPTION

   d) Wait at least 30 sec. before evaluating the next sample.

3. Evaluate the FLAVOR of all samples:

   a) Take a bite of cracker.

   b) Rinse with water. DO NOT SWALLOW WATER.
   Wait 30 sec before proceeding.

   c) Take 3 ml of oil into your mouth (Approx. 1/2 the amount in each vial).
   Hold in your mouth for 15 sec., exhaling through your nose several times.
   DO NOT SWALLOW OIL.

   RECORD INTENSITY AND FLAVOR DESCRIPTION

   WAIT BEFORE RINSING TO EVALUATE NOTES IF DESIRED

   d) Wipe your lips with a napkin.

   e) Rinse your mouth with lemon water, swishing the water around in your mouth.
   DO NOT SWALLOW WATER.

   f) Wipe your lips with a napkin.

   g) Take a bite of a cracker.

   h) Rinse your mouth with water, swishing it around in your mouth.
   DO NOT SWALLOW WATER.

   i) Wait at least 30 seconds before tasting the next sample.
   CONTINUE AT 3C.

**EXTRA WATER AVAILABLE IN CORNER

Appendix 4. Scorecards used for the assessment of heated canola oil samples.

NAME ______________________ DATE ____________

SAMPLE CODE							
OVERALL INTENSITY	ODOR	ODOR	ODOR	ODOR	ODOR	ODOR	ODOR
10 bland							
9 trace							
8 faint							
7 slight							
6 mild							
5 moderate							
4 definite							
3 strong							
2 very strong							
1 extreme							

ODOR DESCRIPTION BLANK=NONE 1=VERY SLIGHT 3=MODERATE 5=VERY STRONG

BURNT							
FISHY							
GRASSY							
HEATED							
PAINTY							
RANCID							
RUBBERY							
STALE							
SWEET							
OTHER (specify)							

COMMENTS:

Appendix 4. Continued.

NAME ______________________________ DATE ________________

SAMPLE CODE							
OVERALL INTENSITY	FLAVOR	FLAVOR	FLAVOR	FLAVOR	FLAVOR	FLAVOR	FLAVOR
10 bland							
9 trace							
8 faint							
7 slight							
6 mild							
5 moderate							
4 definite							
3 strong							
2 very strong							
1 extreme							

FLAVOR DESCRIPTION BLANK=NONE 1=VERY SLIGHT 3=MODERATE 5=VERY STRONG

BURNT							
FISHY							
GRASSY							
HEATED							
PAINTY							
RANCID							
RUBBERY							
STALE							
SWEET							
OTHER (specify)							

COMMENTS:

Appendix 5. Odor intensity values[1] for canola oil, with and without antioxidant, following accelerated storage at 65°C.

Odor Note	Storage Time (days)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Buttery	0	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.19	0.10	0.10	0.00
	8	0.00	0.00	0.00	0.05	0.05	0.14
	12	0.00	0.00	0.00	0.00	0.05	0.00
	16	0.00	0.14	0.00	0.00	0.00	0.00
Fishy	0	0.00	0.05	0.05	0.00	0.00	0.00
	4	0.00	0.05	0.05	0.00	0.00	0.00
	8	0.57	0.38	0.00	0.00	0.05	0.00
	12	0.71	0.71*	0.24	0.05	0.05	0.05
	16	0.48	0.52	0.48	0.24	0.38	0.00
Grassy	0	0.00	0.00	0.05	0.05	0.00	0.00
	4	0.19	0.24	0.14	0.14	0.29	0.05
	8	0.00	0.00	0.10	0.14	0.62*	0.14
	12	0.00	0.00	0.00	0.19	0.24	0.00
	16	0.00	0.00	0.00	0.10	0.10	0.10
Nutty	0	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00
	8	0.00	0.00	0.05	0.19	0.10	0.14
	12	0.00	0.05	0.00	0.14	0.19	0.05
	16	0.00	0.00	0.00	0.00	0.00	0.05

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[1] Values are means of 21 scores (7 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 5. Continued.

Odor Note	Storage Time (days)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Painty	0	0.05	0.00	0.00	0.00	0.00	0.00
	4	0.10	0.00	0.00	0.00	0.19	0.00
	8	2.62*	2.24*	0.38*	0.33	0.24	0.00
	12	3.05*	2.71*	1.71*	0.33*	0.62*	0.00
	16	3.43*	2.76*	2.67*	1.86*	1.43*	0.00
Rancid	0	0.00	0.00	0.00	0.00	0.05	0.00
	4	0.19	0.24*	0.57*	0.19	0.14	0.05
	8	0.38	0.52*	0.10	0.00	0.24	0.05
	12	0.24	0.48	0.24	0.24	0.29	0.00
	16	0.33	0.29	0.33	0.29	0.43*	0.00
Sweet	0	0.10	0.00	0.14	0.14	0.19	0.10
	4	0.05	0.05	0.19	0.19	0.05	0.00
	8	0.00	0.00	0.38	0.24	0.10	0.05
	12	0.00	0.10	0.14	0.14	0.14	0.05
	16	0.05	0.00	0.00	0.00	0.00	0.00
Other	0	0.10	0.14	0.19	0.10	0.10	0.05
	4	0.00	0.05	0.57*	0.33*	0.29	0.00
	8	0.00	0.05	0.05	0.10	0.33	0.00
	12	0.00	0.00	0.00	0.00	0.14	0.00
	16	0.10	0.00	0.00	0.00	0.14	0.00

*Indicates >25% usage by panel.

Appendix 6. Flavor intensity values[1] for canola oil, with and without antioxidant, following accelerated storage at 65°C.

		Canola Oil Treatment					
Flavor Note	Storage Time (days)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Buttery	0	0.05	0.10	0.05	0.05	0.33	0.05
	4	0.00	0.05	0.10	0.19	0.05	0.00
	8	0.00	0.00	0.14	0.05	0.05	0.29
	12	0.00	0.19	0.05	0.14	0.10	0.14
	16	0.00	0.00	0.05	0.00	0.05	0.05
Fishy	0	0.00	0.00	0.05	0.00	0.00	0.00
	4	0.00	0.05	0.00	0.00	0.05	0.05
	8	0.38	0.52	0.14	0.19	0.14	0.00
	12	0.62*	0.48*	0.33	0.00	0.00	0.05
	16	0.67*	0.62*	0.38	0.19	0.43*	0.00
Grassy	0	0.05	0.00	0.14	0.14	0.10	0.00
	4	0.05	0.14	0.33	0.19	0.57*	0.05
	8	0.00	0.24	0.43*	0.38	0.71*	0.00
	12	0.00	0.05	0.00	0.52*	0.62*	0.14
	16	0.29	0.00	0.00	0.29	0.57*	0.10
Nutty	0	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.10	0.00	0.00	0.05	0.00
	8	0.00	0.05	0.24	0.24	0.24	0.05
	12	0.00	0.00	0.00	0.33	0.48*	0.00
	16	0.00	0.00	0.00	0.10	0.14	0.00

[1] Values are means of 21 scores (7 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 6. Continued.

Flavor Note	Storage Time (days)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Painty	0	0.00	0.05	0.00	0.14	0.19	0.00
	4	0.19	0.38*	0.19	0.48*	0.24	0.00
	8	3.24*	2.62*	0.43*	0.57*	0.33	0.00
	12	3.43*	2.86*	1.90*	0.67*	0.90*	0.05
	16	3.52*	2.86*	2.33*	1.81*	1.62*	0.00
Rancid	0	0.05	0.00	0.05	0.19	0.14	0.00
	4	0.00	0.10	0.48	0.29	0.43*	0.00
	8	0.14	0.38	0.14	0.33	0.33	0.00
	12	0.52*	0.48*	0.33	0.62*	0.76*	0.05
	16	0.52*	0.29	0.33	0.48*	0.29	0.00
Sweet	0	0.00	0.00	0.05	0.10	0.14	0.10
	4	0.00	0.00	0.00	0.05	0.00	0.00
	8	0.00	0.00	0.05	0.10	0.10	0.00
	12	0.00	0.00	0.00	0.05	0.00	0.05
	16	0.00	0.00	0.00	0.00	0.00	0.05
Other	0	0.00	0.00	0.19	0.05	0.00	0.05
	4	0.05	0.10	0.48	0.29	0.19	0.00
	8	0.00	0.00	0.14	0.19	0.52*	0.00
	12	0.00	0.00	0.00	0.24	0.38	0.10
	16	0.10	0.00	0.00	0.00	0.05	0.00

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*Indicates >25% usage by panel.

Appendix 7. Odor intensity values[1] for canola oil, with and without antioxidant, following exposure to fluorescent light (7532 lux).

		Canola Oil Treatment					
Odor Note	Storage Time (hr)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Buttery	0	0.00	0.00	0.00	0.00	0.00	0.00
	8	0.14	0.19	0.19	0.00	0.00	0.05
	16	0.29	0.29	0.19	0.14	0.19	0.00
	24	0.29	0.19	0.14	0.05	0.10	0.00
Fishy	0	0.00	0.00	0.05	0.00	0.00	0.00
	8	0.24	0.14	0.24	0.19	0.19	0.05
	16	0.38	0.33	0.33	0.48	0.38	0.00
	24	0.48	0.43	0.43	0.52	0.48	0.00
Grassy	0	0.00	0.00	0.05	0.05	0.00	0.00
	8	0.29	0.14	0.19	0.14	0.14	0.00
	16	0.48	0.43	0.43	0.29	0.38	0.00
	24	0.48	0.52	0.48	0.43	0.43*	0.00
Nutty	0	0.00	0.00	0.00	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00	0.00	0.05
	16	0.10	0.00	0.00	0.00	0.00	0.00
	24	0.00	0.05	0.00	0.00	0.00	0.00

---

[1] Values are means of 21 scores (7 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 7. Continued.

Odor Note	Storage Time (hr)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Painty	0	0.00	0.05	0.00	0.00	0.00	0.00
	8	0.00	0.19	0.48*	0.38	0.38	0.00
	16	0.52	0.33	0.43	0.29	0.38	0.00
	24	0.57	0.62	0.48	0.52	0.29	0.00
Rancid	0	0.05	0.10	0.00	0.00	0.05	0.00
	8	0.62*	0.52*	0.43	0.10	0.10	0.05
	16	0.62*	0.67*	0.95*	0.90*	1.05*	0.00
	24	0.90*	1.05*	0.76*	0.76*	0.90*	0.00
Sweet	0	0.05	0.05	0.14	0.14	0.19	0.10
	8	0.10	0.19	0.38	0.24	0.00	0.10
	16	0.19	0.05	0.29	0.19	0.24	0.00
	24	0.05	0.00	0.14	0.19	0.43	0.05
Other	0	0.19	0.00	0.19	0.10	0.10	0.05
	8	0.76*	0.71*	0.38*	0.38	0.57	0.05
	16	0.57*	0.62*	0.57*	0.57*	0.62*	0.00
	24	0.67*	0.81*	0.95*	0.48*	0.71*	0.14

*Indicates >25% usage by panel.

Appendix 8. Flavor intensity values[1] for canola oil, with and without antioxidant, following exposure to fluorescent light (7532 lux).

		Canola Oil Treatment					
Flavor Note	Storage Time (hr)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Buttery	0	0.05	0.00	0.05	0.05	0.33	0.05
	8	0.14	0.10	0.29	0.14	0.10	0.00
	16	0.10	0.05	0.10	0.10	0.14	0.00
	24	0.10	0.10	0.05	0.14	0.00	0.19
Fishy	0	0.00	0.00	0.05	0.00	0.00	0.00
	8	0.19	0.29	0.14	0.33	0.29	0.00
	16	0.48	0.29	0.29	0.38	0.29	0.00
	24	0.57*	0.67*	0.57	0.57*	0.71	0.00
Grassy	0	0.05	0.00	0.14	0.14	0.10	0.00
	8	0.48*	0.57*	0.57*	0.76*	0.57*	0.00
	16	0.81*	0.81*	1.00*	0.81*	0.81*	0.00
	24	0.81*	0.86*	0.95*	0.67*	0.90*	0.00
Nutty	0	0.00	0.00	0.00	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00	0.05	0.00
	16	0.00	0.05	0.00	0.00	0.00	0.00
	24	0.00	0.05	0.00	0.00	0.00	0.00

[1] Values are means of 21 scores (7 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 8. Continued.

		Canola Oil Treatment					
Flavor Note	Storage Time (hr)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Painty	0	0.10	0.10	0.00	0.14	0.19	0.00
	8	0.57*	0.76*	0.90*	0.86*	0.86*	0.00
	16	0.95*	1.00*	1.10*	1.00*	0.95*	0.00
	24	1.38*	1.05*	1.10*	1.10*	0.90*	0.00
Rancid	0	0.10	0.00	0.05	0.19	0.14	0.00
	8	0.48*	0.29	0.33*	0.38*	0.38	0.00
	16	0.48*	0.71*	0.62*	0.71*	0.57*	0.00
	24	0.71*	0.81*	0.71*	0.67*	0.76*	0.00
Sweet	0	0.05	0.10	0.05	0.10	0.14	0.10
	8	0.00	0.00	0.10	0.00	0.10	0.00
	16	0.00	0.00	0.14	0.00	0.00	0.00
	24	0.05	0.00	0.14	0.10	0.10	0.00
Other	0	0.00	0.00	0.19	0.05	0.00	0.05
	8	0.24	0.14	0.52*	0.29	0.33	0.00
	16	0.48	0.38*	0.48	0.38*	0.33	0.05
	24	0.19	0.62*	0.29	0.19	0.48	0.00

*Indicates >25% usage by panel.

Appendix 9. Odor intensity values[1] for canola oil, with and without antioxidant, following practical storage.

Odor Note	Storage Time (months)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Buttery	0	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.10	0.10	0.00	0.05	0.19	0.00
	10	0.24	0.19	0.00	0.00	0.05	0.00
Fishy	0	0.00	0.05	0.05	0.00	0.00	0.00
	5	0.19	0.05	0.48	0.48	0.48	0.00
	10	0.24	0.05	0.10	0.10	0.10	0.00
Grassy	0	0.00	0.00	0.05	0.05	0.00	0.00
	5	0.24	0.48	0.43	0.48	0.38	0.00
	10	0.38	0.71*	0.10	0.24	0.38	0.10
Nutty	0	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.01	0.29	0.00	0.00	0.00	0.05
	10	0.19	0.43	0.29	0.14	0.29	0.00
Painty	0	0.05	0.00	0.00	0.00	0.00	0.00
	5	0.57	0.71*	0.48*	0.33	0.29	0.00
	10	0.62	0.86*	0.62*	0.14	0.24	0.00
Rancid	0	0.00	0.00	0.00	0.00	0.05	0.00
	5	0.48*	0.62*	0.86*	0.62	0.90*	0.05
	10	0.62*	0.95*	0.81*	0.62*	0.76*	0.00
Sweet	0	0.10	0.00	0.14	0.14	0.19	0.00
	5	0.19	0.14	0.19	0.29	0.38	0.05
	10	0.00	0.14	0.29	0.14	0.00	0.00
Other	0	0.10	0.14	0.19	0.10	0.10	0.05
	5	0.57*	0.52	1.05*	0.52*	1.05*	0.10
	10	0.24	0.33	0.48	0.76*	0.86*	0.19

[1] Values are means of 21 scores (7 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 10. Flavor intensity values[1] for canola oil, with and without antioxidant, following practical storage.

Flavor Note	Storage Time (months)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Buttery	0	0.05	0.10	0.05	0.05	0.33	0.05
	5	0.00	0.10	0.10	0.00	0.00	0.00
	10	0.19	0.14	0.10	0.24	0.05	0.00
Fishy	0	0.00	0.00	0.05	0.00	0.00	0.00
	5	0.24	0.10	0.67	0.67*	0.62*	0.00
	10	0.24	0.62*	0.19	0.10	0.19	0.00
Grassy	0	0.05	0.00	0.14	0.14	0.10	0.00
	5	0.76*	0.86*	0.90*	0.67	0.86*	0.10
	10	0.43*	0.95*	0.57*	0.48*	0.71*	0.00
Nutty	0	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.14	0.05	0.00	0.00	0.00
	10	0.43	0.48	0.43	0.29	0.43	0.00
Painty	0	0.00	0.05	0.00	0.14	0.19	0.00
	5	0.95*	0.76*	1.24*	1.19*	1.05*	0.00
	10	0.90*	0.95*	0.71*	0.48*	0.48*	0.00
Rancid	0	0.05	0.00	0.05	0.19	0.14	0.00
	5	0.52*	0.52*	0.76*	0.90*	0.81*	0.05
	10	0.67*	0.90*	0.52	0.90*	0.95*	0.00
Sweet	0	0.00	0.00	0.05	0.10	0.14	0.10
	5	0.10	0.19	0.05	0.05	0.05	0.00
	10	0.00	0.05	0.05	0.10	0.19	0.05
Other	0	0.00	0.00	0.19	0.05	0.00	0.05
	5	0.29	0.24	0.95*	0.57*	0.71*	0.05
	10	0.29	0.33	0.76*	1.09*	1.05*	0.10

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[1] Values are means of 21 scores (7 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 11. Odor intensity values[1] for canola oil, with and without antioxidant, following deep fat heating (185°C).

Odor Note	Heating Time (min)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Burnt	0	0.00	0.04	0.00	0.00	0.00	0.00
	20	0.00	0.00	0.00	0.08	0.17	0.00
	40	0.08	0.00	0.17	0.12	0.08	0.00
	60	0.25	0.04	0.00	0.08	0.12	0.00
Fishy	0	0.46*	0.50	0.46	0.29	0.46	0.00
	20	0.92*	0.42*	0.62*	0.54*	0.54*	0.00
	40	0.46	0.62*	0.54*	0.71*	0.50*	0.00
	60	0.54*	0.33	0.71*	0.38	0.50*	0.00
Grassy	0	0.08	0.04	0.00	0.29	0.17	0.12
	20	0.00	0.00	0.08	0.04	0.12	0.04
	40	0.08	0.00	0.00	0.00	0.00	0.04
	60	0.08	0.04	0.08	0.00	0.12	0.00
Heated	0	0.46*	0.71*	0.54*	0.46*	0.42	0.00
	20	1.17*	0.62*	1.08*	0.92*	1.04*	0.00
	40	1.12*	1.12*	1.04*	1.17*	1.04*	0.00
	60	1.08*	1.08*	1.25*	1.08*	0.88*	0.00
Painty	0	1.17*	1.00*	1.00*	0.79*	0.83*	0.00
	20	1.58*	1.25*	1.75*	1.46*	1.58*	0.00
	40	1.38*	0.92*	1.38*	1.46*	1.58*	0.00
	60	1.71*	1.67*	1.62*	1.50*	2.00*	0.00

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[1] Values are means of 24 scores (8 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 11. Continued.

Odor Note	Heating Time (min)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
		Canola Oil Treatment					
Rancid	0	0.33	0.29	0.25	0.25	0.46	0.00
	20	0.79*	0.50	0.54	0.75*	0.46	0.00
	40	0.75*	0.79*	0.71*	0.71	0.71*	0.00
	60	0.71*	0.79*	0.67*	0.75*	0.83*	0.00
Rubbery	0	0.04	0.00	0.00	0.00	0.00	0.00
	20	0.00	0.00	0.00	0.08	0.00	0.00
	40	0.08	0.04	0.00	0.00	0.00	0.00
	60	0.04	0.08	0.04	0.12	0.00	0.04
Stale	0	0.21	0.25	0.12	0.08	0.04	0.08
	20	0.17	0.42*	0.42	0.25	0.46	0.00
	40	0.42	0.25	0.50	0.29	0.33	0.04
	60	0.67	0.12	0.33	0.17	0.08	0.04
Sweet	0	0.00	0.00	0.08	0.04	0.21	0.17
	20	0.00	0.04	0.04	0.04	0.04	0.12
	40	0.08	0.00	0.04	0.04	0.00	0.21
	60	0.04	0.00	0.00	0.17	0.04	0.12
Other	0	0.17	0.04	0.29	0.25	0.71*	0.12
	20	0.17	0.00	0.17	0.12	0.08	0.00
	40	0.25	0.04	0.12	0.08	0.00	0.08
	60	0.12	0.25	0.08	0.12	0.00	0.12

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*Indicates >25% usage by panel.

Appendix 12. Flavor intensity values[1] for canola oil, with and without antioxidant, following deep fat heating (185°C).

Flavor Note	Heating Time (min)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Burnt	0	0.00	0.00	0.04	0.00	0.00	0.00
	20	0.00	0.08	0.04	0.08	0.08	0.00
	40	0.08	0.00	0.00	0.00	0.08	0.00
	60	0.04	0.04	0.17	0.00	0.00	0.00
Fishy	0	0.88*	0.17	0.38	0.42*	0.29	0.00
	20	0.54*	0.67*	0.58*	0.50*	0.58*	0.00
	40	0.12	0.21	0.58*	0.38*	0.17	0.00
	60	0.79*	0.75*	0.62*	0.71*	0.46*	0.00
Grassy	0	0.00	0.00	0.00	0.08	0.29	0.00
	20	0.00	0.00	0.00	0.00	0.08	0.00
	40	0.00	0.08	0.04	0.08	0.17	0.00
	60	0.00	0.04	0.00	0.12	0.12	0.00
Heated	0	0.42	0.50*	0.71*	0.42	0.46	0.00
	20	0.92*	0.62*	0.96*	0.88*	1.12*	0.00
	40	1.12*	1.04*	0.79*	1.00*	1.08*	0.00
	60	1.17*	0.92*	0.92*	0.75*	1.08*	0.00
Painty	0	1.08*	1.29*	1.17*	0.79*	0.71*	0.00
	20	2.08*	1.12*	1.54*	1.29*	1.50*	0.00
	40	1.67*	1.54*	1.25*	1.25*	1.71*	0.00
	60	1.38*	1.54*	1.54*	1.58*	1.54*	0.00

[1] Values are means of 24 scores (8 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 12. Continued.

Flavor Note	Heating Time (min)	Canola Oil Treatment Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Rancid	0	0.71*	0.88*	0.67*	0.62*	0.62*	0.00
	20	0.75*	0.58*	0.75*	0.50*	0.71	0.00
	40	0.83*	0.75*	0.67*	0.92*	0.88*	0.00
	60	0.67*	0.71*	0.83*	0.71*	0.79*	0.04
Rubbery	0	0.00	0.00	0.00	0.00	0.08	0.00
	20	0.00	0.00	0.00	0.00	0.12	0.00
	40	0.00	0.04	0.00	0.00	0.00	0.00
	60	0.00	0.08	0.00	0.00	0.00	0.00
Stale	0	0.29	0.46	0.29	0.17	0.29	0.00
	20	0.08	0.38	0.25	0.25	0.21	0.00
	40	0.54	0.29	0.12	0.50	0.38	0.00
	60	0.04	0.25	0.17	0.00	0.29	0.00
Sweet	0	0.00	0.00	0.04	0.08	0.29	0.04
	20	0.00	0.04	0.00	0.04	0.00	0.00
	40	0.00	0.00	0.00	0.04	0.00	0.00
	60	0.04	0.00	0.00	0.00	0.00	0.00
Other	0	0.00	0.08	0.04	0.12	0.21	0.04
	20	0.04	0.12	0.04	0.00	0.04	0.04
	40	0.12	0.08	0.04	0.04	0.04	0.00
	60	0.12	0.12	0.04	0.04	0.00	0.08

*Indicates >25% usage by panel.

Appendix 13. Odor intensity values[1] for canola oil, with and without antioxidant, following shallow pan heating (185°C).

Odor Note	Heating Time (min)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Burnt	0	0.00	0.00	0.00	0.08	0.00	0.00
	6	0.04	0.04	0.00	0.04	0.00	0.00
	12	0.12	0.00	0.04	0.00	0.00	0.00
Fishy	0	0.21	0.25	0.21	0.17	0.04	0.00
	6	0.42*	0.29	0.42	0.46	0.33	0.00
	12	0.54*	0.12	0.38*	0.67*	0.42*	0.04
Grassy	0	0.00	0.08	0.00	0.08	0.08	0.04
	6	0.04	0.00	0.00	0.00	0.00	0.00
	12	0.00	0.00	0.12	0.00	0.00	0.08
Heated	0	0.42*	0.38*	0.29	0.29	0.21	0.00
	6	0.79*	0.75*	0.54*	0.46*	0.58*	0.04
	12	0.75*	0.92*	0.79*	0.54*	0.46*	0.00
Painty	0	0.58*	0.54*	0.42*	0.17	0.12	0.00
	6	0.96*	1.00*	0.58*	0.75*	1.25*	0.00
	12	0.67*	1.08*	1.25*	0.71*	1.00*	0.00

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[1] Values are means of 24 scores (8 panelists, 3 replications).

[*] Indicates >25% usage by panel.

Appendix 13. Continued.

		Canola Oil Treatment					
Odor Note	Heating Time (min)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Rancid	0	0.50	0.25	0.29	0.50	0.12	0.00
	6	1.00*	0.42	0.38	0.21	0.50*	0.00
	12	0.88*	0.58*	0.67*	0.75*	0.62*	0.00
Rubbery	0	0.00	0.00	0.00	0.00	0.00	0.04
	6	0.00	0.00	0.00	0.00	0.00	0.00
	12	0.00	0.00	0.00	0.00	0.00	0.00
Stale	0	0.29	0.29*	0.29*	0.12	0.12	0.12
	6	0.42	0.17	0.46*	0.21	0.33	0.04
	12	0.33	0.33	0.42	0.25	0.50	0.00
Sweet	0	0.04	0.00	0.04	0.08	0.25	0.08
	6	0.00	0.17	0.04	0.04	0.17	0.21
	12	0.00	0.04	0.00	0.04	0.00	0.04
Other	0	0.17	0.04	0.29	0.62*	0.46	0.17
	6	0.17	0.00	0.33	0.12	0.00	0.00
	12	0.08	0.00	0.00	0.29	0.17	0.04

*Indicates >25% usage by panel.

Appendix 14. Flavor intensity values[1] for canola oil, with and without antioxidant, following shallow pan heating (185°C).

		Canola Oil Treatment					
Flavor Note	Heating Time (min)	Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Burnt	0	0.00	0.00	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.00	0.00	0.00	0.00
	12	0.12	0.00	0.00	0.00	0.00	0.00
Fishy	0	0.17	0.12	0.21	0.12	0.08	0.21
	6	0.25	0.12	0.08	0.21	0.17	0.04
	12	0.54*	0.17	0.42	0.50*	0.21	0.00
Grassy	0	0.04	0.08	0.08	0.12	0.33*	0.21
	6	0.12	0.00	0.00	0.00	0.04	0.00
	12	0.08	0.00	0.04	0.04	0.04	0.12
Heated	0	0.46*	0.50*	0.33	0.25	0.25	0.00
	6	0.75*	0.71*	0.46*	0.54*	0.58*	0.00
	12	0.67*	0.67*	0.71*	0.58*	0.62*	0.00
Painty	0	0.88*	0.79*	0.46*	0.04	0.25	0.00
	6	0.92*	0.46*	1.04*	0.71*	0.75*	0.00
	12	0.92*	1.12*	1.04*	0.50*	1.08*	0.04

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[1] Values are means of 24 scores (8 panelists, 3 replications).

*Indicates >25% usage by panel.

Appendix 14. Continued.

Flavor Note	Heating Time (min)	Canola Oil Treatment					
		Untreated Control (T1)	BHA/BHT (100 ppm ea) + CA (T2)	AP (100 ppm) (T3)	AP (200 ppm) (T4)	AP (200 ppm) + CA (T5)	Hidden Control (T6)
Rancid	0	0.42	0.54	0.25	0.42	0.38*	0.04
	6	0.54*	0.50*	0.38	0.42*	0.58*	0.00
	12	0.58*	0.58*	0.46	0.71*	0.71*	0.00
Rubbery	0	0.00	0.00	0.12	0.00	0.04	0.00
	6	0.00	0.00	0.00	0.00	0.00	0.00
	12	0.00	0.00	0.04	0.00	0.00	0.00
Stale	0	0.42	0.46*	0.33*	0.46	0.33*	0.00
	6	0.50	0.29	0.25	0.38	0.46	0.04
	12	0.38	0.54*	0.33	0.50*	0.46	0.00
Sweet	0	0.00	0.00	0.04	0.00	0.00	0.00
	6	0.00	0.04	0.00	0.00	0.00	0.12
	12	0.00	0.00	0.00	0.00	0.00	0.00
Other	0	0.04	0.00	0.00	0.38*	0.25	0.04
	6	0.04	0.21	0.08	0.00	0.08	0.00
	12	0.00	0.12	0.08	0.04	0.12	0.00

* Indicates >25% usage by panel.